

BARRIERS TO INCREASING THE MARKET SHARE OF WOOD-FRAMED CLOSED PANELS

**ENERGY EFFICIENT INDUSTRIALIZED HOUSING
RESEARCH PROGRAM**

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CENTER FOR HOUSING INNOVATION
UNIVERSITY OF OREGON
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1.0 EXECUTIVE SUMMARY

The University of Oregon completed diagnostic testing of six units of housing which used *open* and *closed* panels. *Open* panels are built with wood studs and shipped to the site with sheathing, and sometimes windows and siding installed, but without insulation, vapor barriers, drywall, or wiring. *Closed* panels by contrast usually arrive at the site with insulation, vapor barriers, and electrical chases installed. The testing indicated that the units constructed of wood-framed *closed* panels performed better thermally than *open* framed panels. Despite the increased energy efficiency and value added, panel manufacturers are reluctant to produce wood-framed closed panels due to many perceived barriers.

Currently about 40% of U.S. homes are built from panels. Most of these panels are predominantly wood-framed open panels which are finished in the field. Wood-framed closed panels represent an opportunity for greater value and energy efficiency. In addition to increased energy efficiency, inherent to closed panels are increased quality control and cost savings available in the factory. Currently only 6% of panel manufacturers are producing wood-framed closed panels due to a host of barriers both real and perceived. This report identifies those barriers as well as strategies to overcome those barriers.

In July and August of 1995, the Energy Studies in Buildings Laboratory surveyed 363 panel building manufacturers to assess the panel industry and the products being produced by panel manufacturers. A list of barriers to wood-framed closed panels was developed through discussions with selected manufacturers, field investigations of panel production, and interviews with building code officials.

Panel manufacturers were most often concerned with the profitability of a wood-framed closed panel and the potential market. Specific barriers included:

- Lack of flexibility in field installation of panels
- Codes and inspection requirements
- Construction trades
- Shipping and transportation of closed panels
- Lack of awareness of closed panels by builders/owners

- Lack of knowledge concerning required manufacturing equipment to move production from open to closed panels
- Perceived loss of design flexibility

Several approaches are possible to reduce the barriers to wood-framed closed panels. Strategies to reduce barriers include educating builders and the public to the benefits of wood-framed closed panels, educating builders to new construction techniques, revising of the code approval process at the federal, state, and local levels, and establishing manufacturing consortiums to share costs of code approval and marketing. Technical innovations could also increase the flexibility of construction with wood-framed closed panels with the use of new materials such as Fiber Reinforced Gypsum Board to increase the durability of panels, especially to prevent damage during shipping and transportation.

2.0

INTRODUCTION

The University of Oregon completed diagnostic testing of six units of housing which used *open* and *closed* panels. *Open* panels are built with wood studs and shipped to the site with sheathing, and sometimes windows and siding installed, but without insulation, vapor barriers, drywall, or wiring. *Closed* panels by contrast usually come to the site with insulation, vapor barriers, and electrical chases installed. The testing indicated that the units constructed of wood-framed *closed* panels performed better thermally than wood-framed *open* panels. Despite the increased energy efficiency and value added, panel manufacturers are reluctant to produce wood-framed closed panels due to many perceived barriers.



Figure 2.1

Construction of a 2-Story Wood-Framed Closed Panel Duplex by Soft Tech of Springfield, Oregon. Closed panels come to the site sided, insulated and wrapped in polyethylene membrane.

In July and August of 1995, the Energy Studies in Buildings Laboratory surveyed 363 panel building manufacturers to assess the panel industry and the products being produced by panel manufacturers. A list of barriers to closed panel was developed through discussions with selected manufacturers, field investigations of panel production and interviews with building code officials. This report

presents the results of the panel manufacture survey, a list of market barriers to wood-framed closed panels and strategies to overcome these barriers.

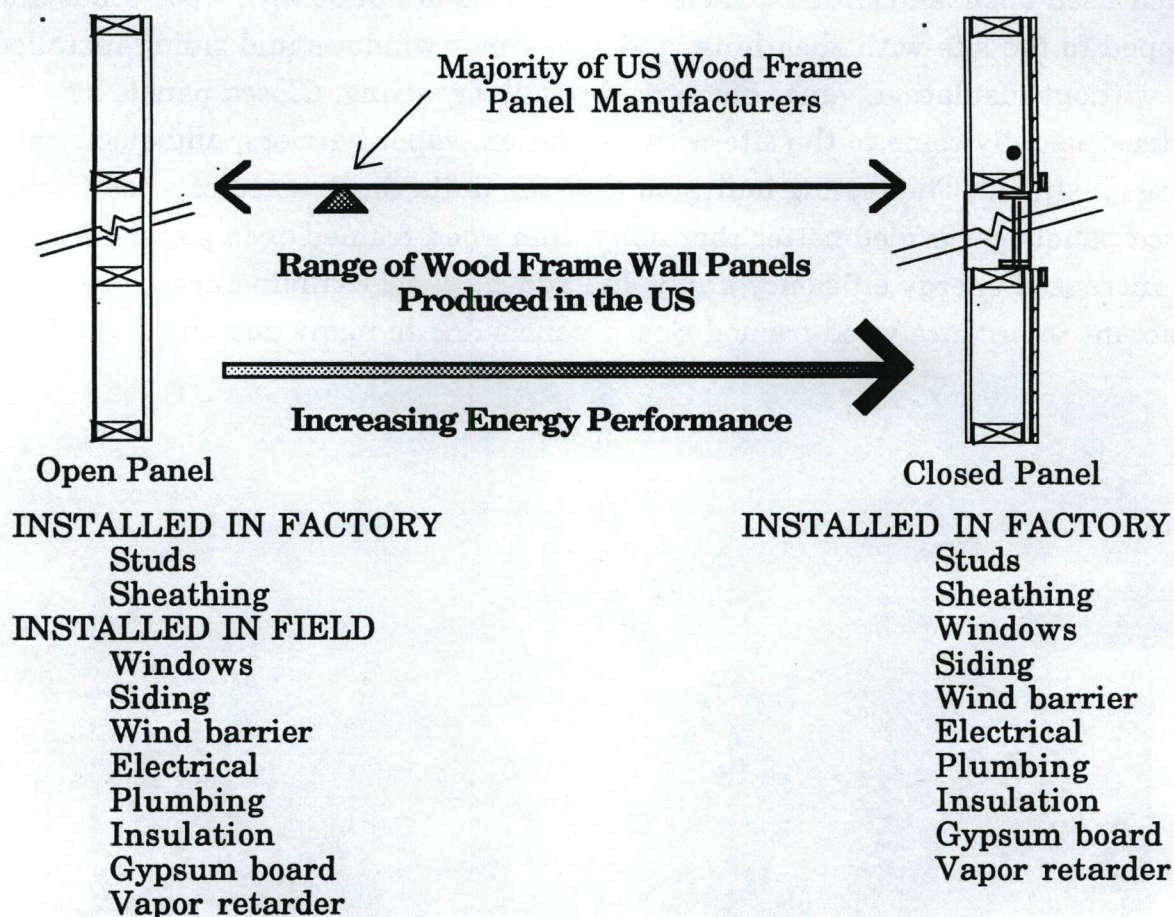


Figure 2.2
Range of Value and Energy Efficiency Added to Manufactured Panels

2.1 DESCRIPTION OF CLOSED PANELS AND OPEN PANELS

Manufacturers of housing panels produce various forms of panels including wood-framed open panels, wood-framed closed panels, steel stud panels, and stressed skin insulating core panels. Stressed skin insulating core panels were considered to be a specific category of panel type, although they are similar to closed frame panels as they are sheathed on both sides. *Open* panels are defined, for this report, as panels with studs and sheathing only on one side. Windows, doors and siding may be incorporated into the panel, but insulation, vapor

barriers, wiring and interior drywall are not added to *open* panels. *Closed* panels are defined as wood frame stud panels which arrive at the site with insulation and a minimum of a vapor barrier. Usually a closed panel will also have an interior layer of gypsum board; however, the degree to which materials and value are added to panels varies among manufacturers. For example, one manufacturer may simply construct a *closed* panel with an unfinished exterior of OSB skin, studs, insulation and a vapor barrier. Other manufacturers may produce a panel which includes a finished exterior layer, OSB, studs, insulation and interior drywall.

2.2 DESCRIPTION OF PANELIZED HOUSING INDUSTRY

In 1994, an estimated 625,000 units of panelized housing were constructed, an estimated 14% increase in panelized housing from 1993 to 1994. Between the years of 1984 to 1995, production of panelized housing increased an estimated 27%. In addition, the market share of panelized housing has increased from 28% to 38% from 1984 to 1994. The increase in market share of panelized housing occurred despite a 5% decrease in the number of housing starts. Industrialized housing includes production builders, panelized, modular and HUD-code buildings (*Automated Builder* p. 30, January 1995).

In addition to an expanding domestic market, export markets represent an area for growth. In 1993, Japan announced an initiative to import 50,000 homes by 1999. The Japanese have taken this initiative because imported homes are cost effective compared to site-built Japanese homes, and panel imports represent an effective strategy to reduce the Japanese trade deficit (*Automated Builder* p. 22, Nov. 1993).

2.3 ADVANTAGES OF WOOD-FRAMED CLOSED PANELS

Closed panels have many advantages as compared to open panels, including higher levels of quality control, lower costs, and increased energy efficiency. In a recent evaluation of manufactured housing that compared the thermal performance of open panels, closed panels, and SSIC panels, thermographic scans detected more thermal defects in the insulation in open panels and site

installed insulation compared to the insulation in closed panels (ESBL, Thermal Testing Report, p. 3). In addition, the open panel units were found to have the highest rates of infiltration, indicating a possible link between infiltration and panel type.

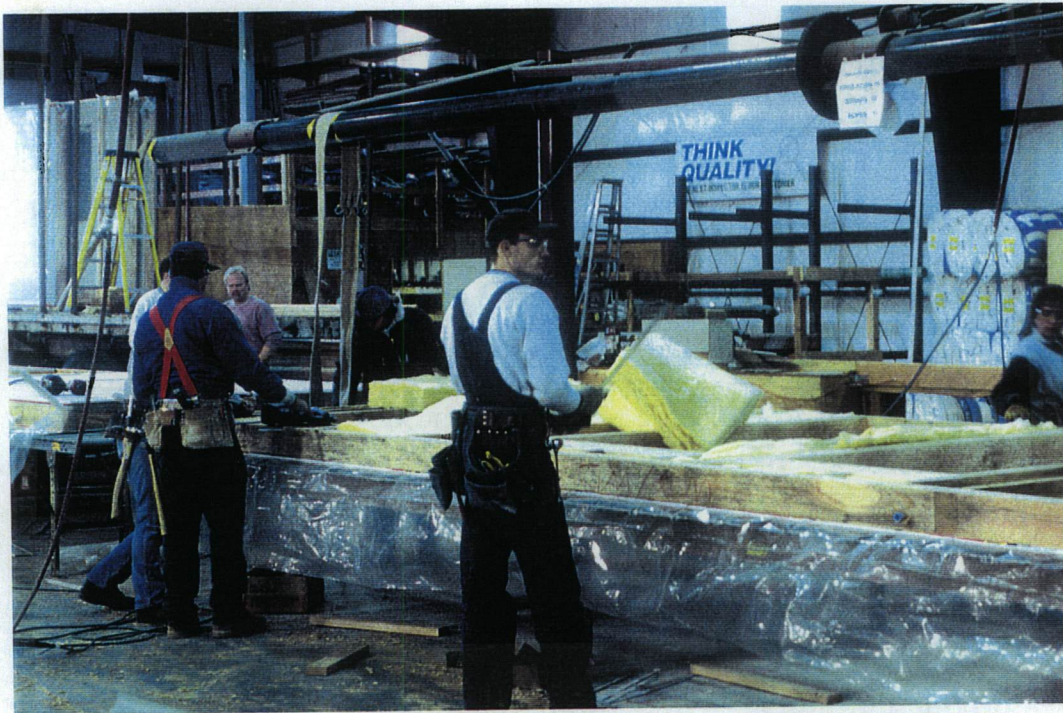


Figure 2.3
Installation of Insulation in the Factory

The superior energy efficiency of closed panels is in part due to the increased levels of quality control achievable in the factory. Installation of insulation in the factory is easier because the insulation is installed in the panel while it remains horizontal, unlike vertical installation in the field. In the factory insulation is installed with a high degree of accuracy, which minimizes buckling and compression.

Closed panels also have inherent cost savings. In the factory, materials such as gypsum wall board and insulation are used efficiently with little waste. Costs of materials are also reduced through large purchase volumes. In addition, insurance costs are lower for factory production as compared to construction in the field. Using closed panels in the field also result in savings due to reduced time of construction and reduced construction waste. Closed panels also give the

developer greater control of the construction process by reducing the amount of sub-contracting. Overall, the use of wood-framed closed panels results in reduced time of construction which results in savings in the cost of financing.

Closed panels also represent an opportunity for panel manufacturers to expand to foreign markets. Closed panels also have greater value added as compared to open panels, which represents an opportunity for increased profit.

3.0 SURVEY OF THE INDUSTRY

Information from manufacturers was gathered by two methods: a request for product information and samples, and a survey. Lists of panel manufacturers were gathered from issues of *Automated Builder's* list of Top 100

Panelizers/Precutters in 1990, SIPA membership, and the ESBL database. On July 3, 1995, 323 letters were sent to panel manufacturers requesting product literature and prices. Letters of requests were primarily sent to companies within the United States; however, 21 were sent to international companies. On July 11, 1995, 321 panel surveys were mailed to the same companies from which product information was requested; in the following weeks, 15 more surveys were mailed bringing the total to 336 surveys mailed.

3.1 SURVEY METHODOLOGY

The panel survey was designed to obtain the following information: whether the manufacturer produced panels, the type of the panel, what percentage of sales was distributed to residential and what percentage to commercial markets, whether the panel was load bearing (gravity), the type of structure, the materials the manufacturer used to produce the panels, whether windows and doors were included in the panels, the method of wiring, methods for plumbing, the type of panel connection, the size of panels, thicknesses of panels, principal markets, method of shipping, and to whom panels are supplied. A copy of the survey is in Appendix A.1.

Of the 336 companies contacted, 38% responded by returning the survey and/or sending product information. Ninety-three companies responded to the survey: 70 manufacturers made panels and 23 did not. Approximately, one fifth (65) of the companies sent product information: 41 made panels and 24 did not. Of the companies not making panels, one business had closed, one stopped due to lack of business, and two were not presently making panels. Half of the companies contacted (169) did not respond to either the request for product literature or the survey. Approximately 12% of the companies (41) had moved – 35 letters and 39 surveys were returned unforwardable.

3.2

SUMMARY OF SURVEY RESULTS

Overall, the survey of panel manufacturers indicates that few manufacturers are producing closed panels, namely panels which include insulation and at least a vapor barrier. Approximately 6% of the 70 responding panel manufacturers produced wood-framed closed panels, as indicated in Figure 3.1. The survey also revealed that some manufacturers produce more than one type of panel. For example, a manufacturer may produce a wood-framed open panel as well as a steel-framed open panel. Consequently, the percentages revealed in figures 3.2 to 3.4 will often add to greater than 100%.

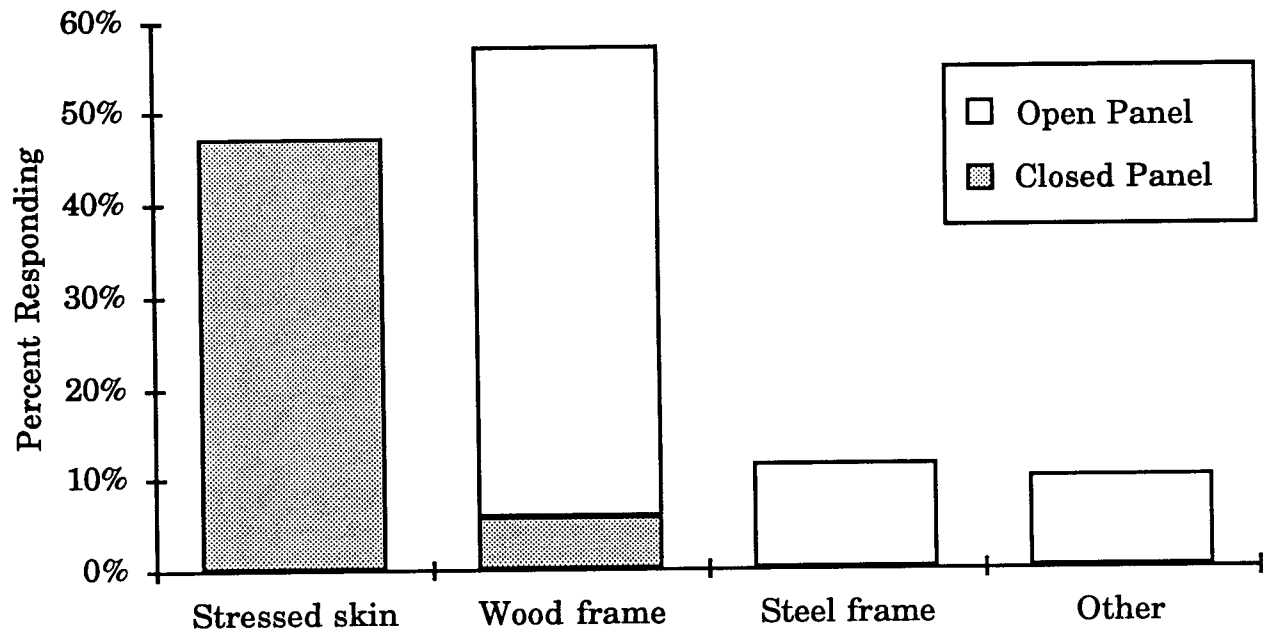


Figure 3.1
Distribution of Panel Types Produced by Manufacturers

The survey also indicated a varying degree in the type of materials manufacturers would add to a panel. Figure 3.2 to Figure 3.4 reflect the percentages of manufacturers who accommodate windows, doors, plumbing and wiring. Stressed skin panels have been highlighted to differentiate between the more traditional stick-framed panels. Generally, the figures reflect a greater opportunity to add value to manufactured panels.

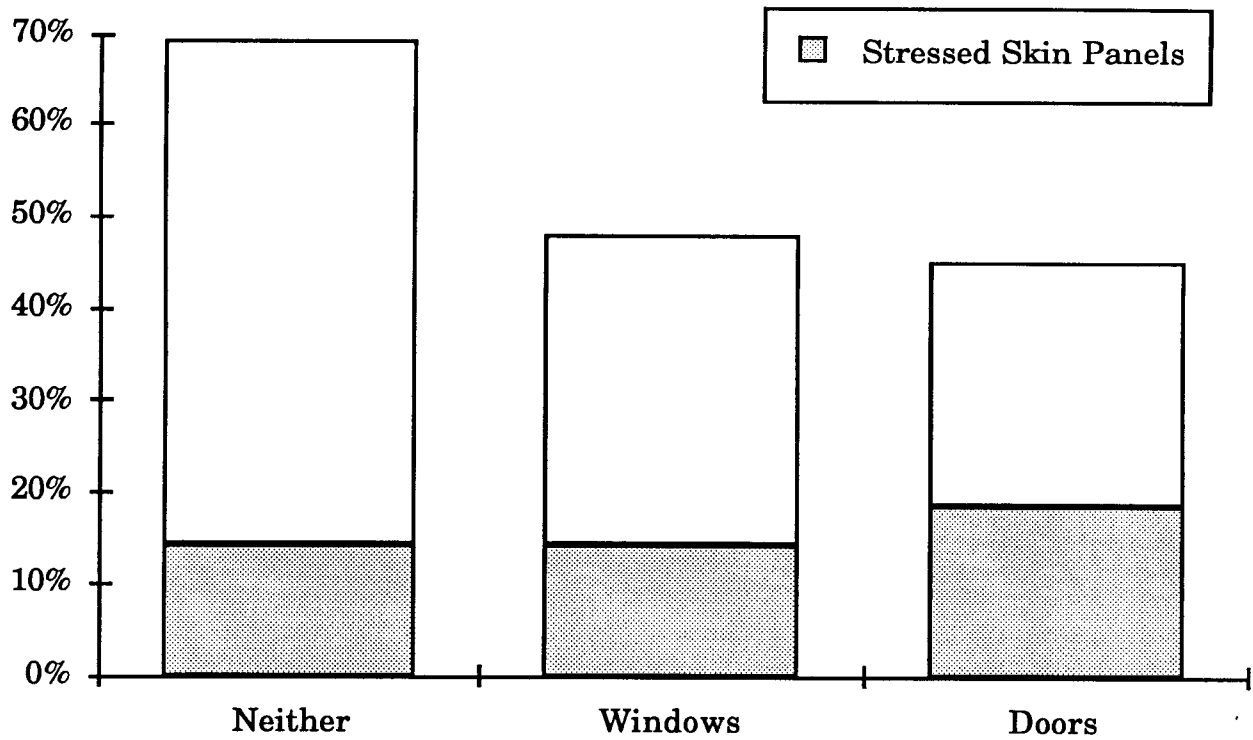


Figure 3.2 Percentages of Manufacturers Who Incorporate Windows and Doors

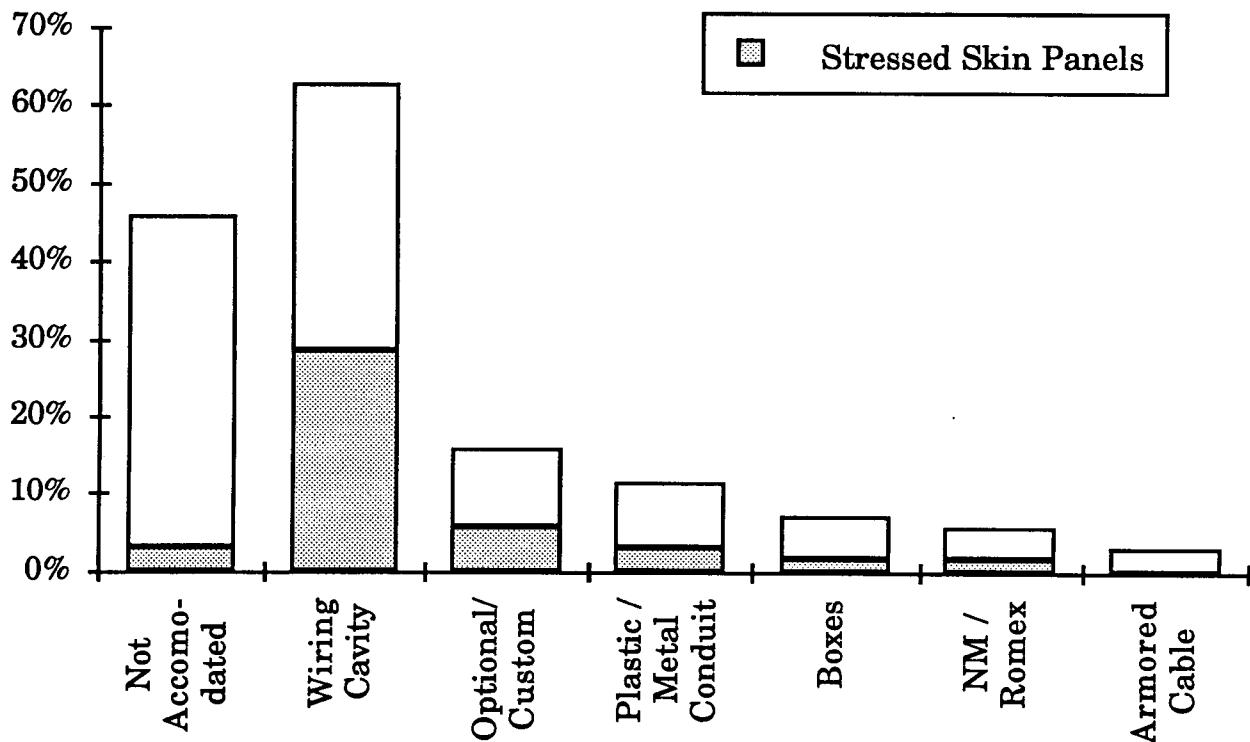


Figure 3.3 Percentages of Manufacturers Who Accommodate Electrical Wiring

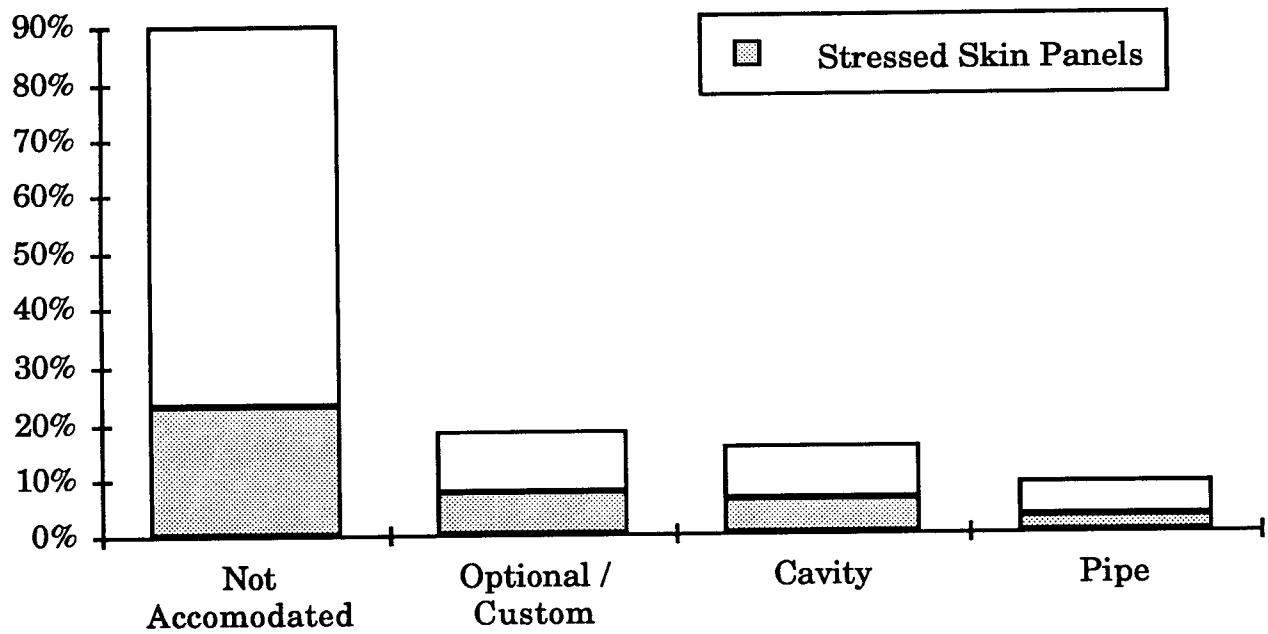


Figure 3.4
Percentages of Manufacturers Who Accommodate Plumbing

4.0 INTERVIEWS WITH MANUFACTURERS

Selected open and closed panel manufacturers were contacted for input on closed and open panels. Manufacturers provided insight into barriers associated with closed panel systems. Often the perspective of a manufacturer was biased by the market they catered to and by the type of panel produced. In general, the two greatest concerns manufacturers wanted to be addressed were the profitability of wood-framed closed panels and the market for wood-framed closed panels.

The most frequent barriers listed by manufacturers to wood-framed closed panels were the following:

- Lack of flexibility in field installation of panels
- Codes and inspection requirements
- Construction trades
- Shipping and transportation of closed panels
- Lack of awareness of closed panels by builders/owners
- Lack of knowledge concerning required manufacturing equipment to move production from open to closed panels
- Perceived loss of design flexibility

As in the construction field in general, there was a wide range of opinion concerning wood-framed closed panels. Open panel manufacturers who did not produce closed panels were generally skeptical of the profitability of wood-framed closed panels. Open panel manufacturers also had misconceptions concerning wood-framed closed panels. For example, one Oregon open panel manufacturer believed that in order to build closed panels every closed panel home would be required to be inspected in the factory as well as in the field. The Oregon manufacturer was unaware of the Oregon State Building Codes manufacturers' compliance program which allows manufacturers to establish a quality assurance program requiring only biannual inspections of the facilities. Open panel manufacturers also had misconceptions concerning the cost of equipment required to expand from open panel construction to closed panel construction.

In general, manufactures require additional equipment to flip panels as well as increased equipment space to convert from open to closed panel production

Manufacturers already producing closed panels for export markets or for domestic markets, generally believed panels were profitable and marketable. However, they cited the barriers they commonly faced were code issues, transportation problems and unfamiliarity of builders and homeowners to the benefits of closed panel construction.

5.0 INTERVIEWS WITH BUILDING CODES OFFICIALS

Code approval was the most frequently listed barrier to wood-framed closed panels. Building codes can often be a problem for closed panel manufacturers as codes often change from state to state and from jurisdiction to jurisdiction. Codes often also restrict the type of components, such as wiring, that can be added to the panel in the factory. Consequently, several interviews with Oregon Building Codes officials were conducted to determine the code officials' perspective on barriers to wood-framed closed panels. In addition, an interview was conducted with an Oregon engineer who has assisted panel manufacturers in achieving Oregon State Code approval for wood-framed closed panels.

5.1 OREGON STATE CODE

An interview was conducted with Chuck Monschein, Assistant Manager of the Oregon Building Codes Division. Currently, in the State of Oregon, the Building Codes Division licenses 151 manufacturers to produce premanufactured structures. The number of licensed manufacturers has increased from 55 to 151 manufacturers in a period of five years. Of the 151 manufacturers, nine are licensed to produce closed wall panels. One of these nine are producing wood-framed closed panels for domestic residential buildings.

In the State of Oregon, distinctions between "open" and "closed" construction determine whether a panel must receive an Oregon State Insignia or "Blue Tag" representing compliance. "Closed construction means a factory assembled roof, wall, or floor panel or component which may enclose factory installed structural, mechanical, electrical, plumbing or energy conservation equipment or material and is not entirely open for visual inspection of the equipment systems or structure at the site" (p. 1, Oregon Administration Rules, Division 674, Prefabricated Construction). If a panel is not "closed", meaning that all structural, electrical and mechanical systems are visible, the panel falls under local jurisdiction.

In Oregon, there are two paths for closed panel code approval: through the Building Codes Division Compliance Control process or through the

Manufacturers' Compliance Control program. The Division Compliance Control program is more dependent upon the actual Building Codes Division. The Building Codes Division uses their compliance program and supplies their inspectors to ensure conformance. The Manufacturers' Compliance Control Program is generally more self directed by the manufacturer. An outline of the Compliance Control Program process follows:

Process for the Manufacturer's Compliance Program

- The manufacturer submits plans, specifications and supporting engineering documentation. The documents submitted detail all conditions for the designs to be constructed.
- The manufacturer submits a Compliance Control Manual. The Compliance Control Manual is divided into an administrative section and a technical section. The administrative section includes names of company officials, resumes of key personnel, organizational structure of the company, and responsibilities of personnel. Also included are quality control procedures, provisions for keeping the Compliance Control Manual current, and a glossary of terms. The technical section provides a detailed description of the production process, which includes a production flow chart, product specifications, manufacturing tolerances, classification of defects, a list of major production equipment, incoming inspections and tests, process in quality control, nonconforming materials, measuring equipment and data collection systems.
- The Codes Division reviews the plans; the typical review period is approximately two weeks.
- The Codes Division reviews the Compliance Control Manual
- The Codes Division performs an initial audit lasting approximately three hours. Inspection and travel time are billed at \$60 per hour.
- Approval for prefabricated structures lasts for a period of one year after the

initial audit. Approval is renewed annually by an unannounced audit on or about a manufacturer's anniversary date. (Manufacturer's Compliance Control Program, p. 4)

- Additional changes to design or the choice of a new product can be made to any compliance control program to allow changes in construction or design. Chuck Monschein estimated a review time of approximately one week for any modifications to the approved panel construction or design.

Chuck Monschein also listed the following common problems manufacturers experience in the code approval process for closed construction.

- The Manufacturer changes a process in their compliance manual without submitting a change to the Building Codes Division. For example, the manufacturer cannot change orientation of plywood or OSB.
- Manufacturers sometimes submit complicated specifications that result in errors in the factory. For example, a manufacturer may have several wall lengths that all require different sized sheathing. Workers may often inadvertently apply the wrong sheathing for a specific wall size. Monschien encourages manufacturers to adopt a simplified program that utilizes one size sheathing. Often, additional shear strength may be found in siding, so a manufacture does not have to specify the largest width sheathing.
- Manufacturers produce designs that call for a mixture of stick built and panelized construction. By law, the Building Codes Division can only approve *closed* panel construction. Consequently, the proposed design requires the approval of the state's Prefabricated division as well as local jurisdictions. The mixing of panelized techniques with traditional techniques often confuses the manufacturer and the code officials.
- The code approval process is governed by legal statutes that are often confusing to manufacturers. The Building Codes Division will provide consulting to manufacturers for preparation of compliance programs and general advice at a rate of \$15 per hour.

Chuck Monschein's advice for a smooth approval process:

- Consistency of design
- A design compliance program for ease of construction
- Clear documentation of construction and the range of options
- A design that allows for the greatest flexibility and specifies all conditions. For example, window location is often limited by shear requirements.
- Established credibility with the Building Codes Division

Interview with Jok Ang, Oregon Structural Engineer

An interview was first held with Jok Ang, a structural engineer from Eugene who has assisted manufacturers in achieving Oregon State Code approval for wood-framed closed panels. Ang has assisted in quality control and development of Compliance Manuals for several Oregon panel manufacturers. For Compliance Manuals, Ang generally performs the following tasks:

- Calculate loads for all connections and details
- Analyze wind and snow loads for three to four regions
- Establish allowable conditions for one panel
- Review calculations

Ang estimated that the approval process for the compliance manual, including the State's review, requires approximately six months time. Overall, Ang believes Oregon's approval process is similar to Washington State's, except Oregon is a little more "picky."

In addition, Ang is familiar with testing and calculations required under the UBC Code. Ang estimated that it would cost approximately \$10,000 - \$15,000 to develop test and develop a compliance manual to meet UBC standards. In addition, Ang estimated an additional \$5,000 each to adjust the manual to meet BOCA Code and the Southern Code.

6.0 SUMMARY OF MARKET BARRIERS TO CLOSED PANELS

Market barriers to closed panels were identified in the following order of priority:

- Lack of flexibility in field installation of panels
- Codes and inspection requirements
- Construction trades
- Shipping and transportation of closed panels
- Lack of awareness of closed panels by builders/owners
- Lack of knowledge concerning required manufacturing equipment to move production from open to closed panels
- Perceived loss of design flexibility.

These barriers must be addressed to answer the two greatest concerns of panel manufacturers:

- Marketability of wood-framed closed panels
- Profitability of wood-framed closed panels

Market barriers were identified through interviews with manufacturers, code officials, and builders. In addition, manufacturing of closed panel construction was observed.

6.1 LACK OF FLEXIBILITY (INSTALLATION / CONNECTION TO FOUNDATION / WIRING / PLUMBING / JOINTS)

One of the more significant barriers to closed panels is their perceived lack of flexibility for installation in the field. The construction of closed panels in the factory results in a high-quality product with small tolerances for error in the field. Connection of the panels to the foundation, panel-to-panel joints, plumbing and wiring are all unconventional construction practices.

Installation

Wood-framed closed panels require a high degree of construction planning. The closed panels cannot be exposed to rain; consequently, they must either be covered during construction or constructed during clear weather.

The closed panels also are inherently heavier due to the added materials of insulation and drywall. Equipment such as cranes or forklifts are required for on-site installation. As a result, installation of panels must be carefully sequenced to minimize the required time for cranes and to erect the panels as quickly as possible.



Figure 6.1
Workers Guide Wood-Framed Closed Panel Into Place

Connection to Foundation

Field connection of the panels to the foundation differs between open panel and closed panel construction. Open frame panels can be connected to the foundation or flooring with anchor bolts much like traditional stick frame construction. Closed panels, however, are often anchored to foundations through engineered metal straps. Closed panels also require a well-leveled foundation to ensure that panels properly align.

Wiring

Wiring of closed panels is often cited as one of the prime reasons for their lack of flexibility. Again, closed panels disrupt the traditional construction sequence of stick frame construction and open panel construction, which allows electricians to wire in a building during the rough-in stage of construction when only the wood framing and exterior sheathing are in place. Wiring of closed panels also introduces issues of code approval, which vary between states and local jurisdictions.

Several approaches varying from complete wiring in the field to wiring of panels in the factory are possible depending upon the flexibility of building codes. At a minimum level, all wiring can be done through baseboard raceways and electrical chases in the field. Often closed wood framed panels are constructed with electrical chases or electrical conduit installed in the factory. Wiring is then pulled through the chases in the field. In the State of Oregon, conduit and electrical boxes must be installed by a certified electrician in the factory. The ultimate example of prefabrication would be to install wiring, conduit and switches in the factory.

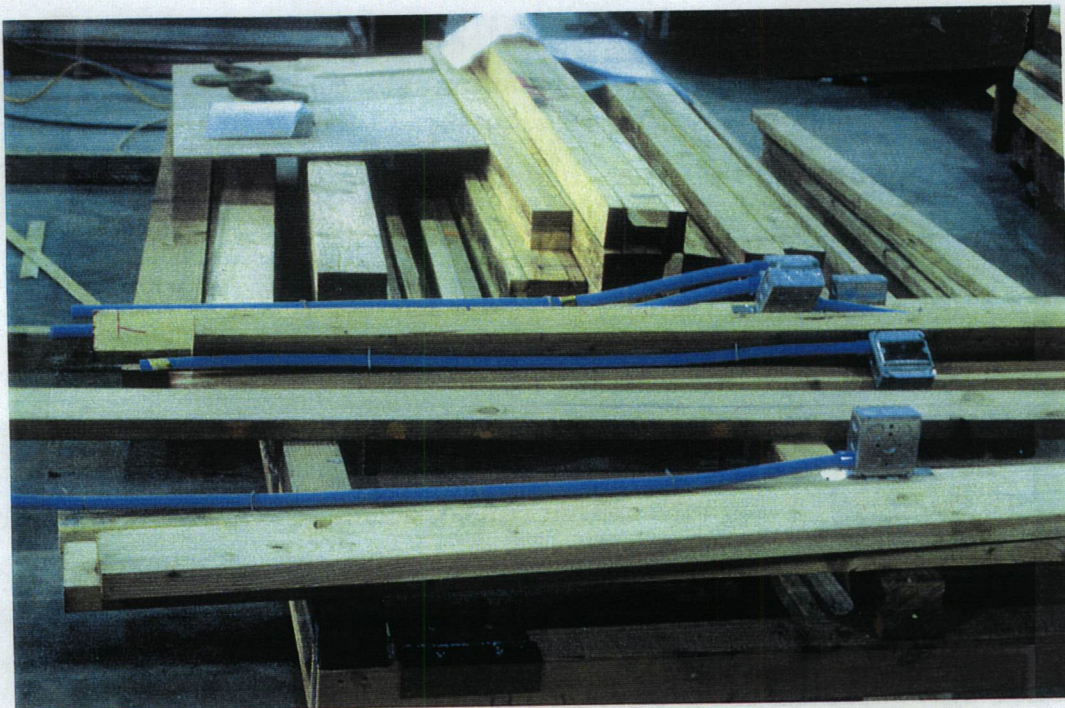


Figure 6.2
Preassembled Wiring Conduit and Electrical Boxes in the Factory

Recent developments of nonmetallic electrical splices, primarily for the HUD code industry, allow the possibility of wiring panels in the factory. Again this is an area where code approval as well as construction trades are large factors. The electrical splices generally snap together and would easily allow prewired panels to be quickly connected together in the field. With the wiring splices much of the electrician's work could be performed in the factory. However, the splices would most likely not eliminate the electrician from the field.

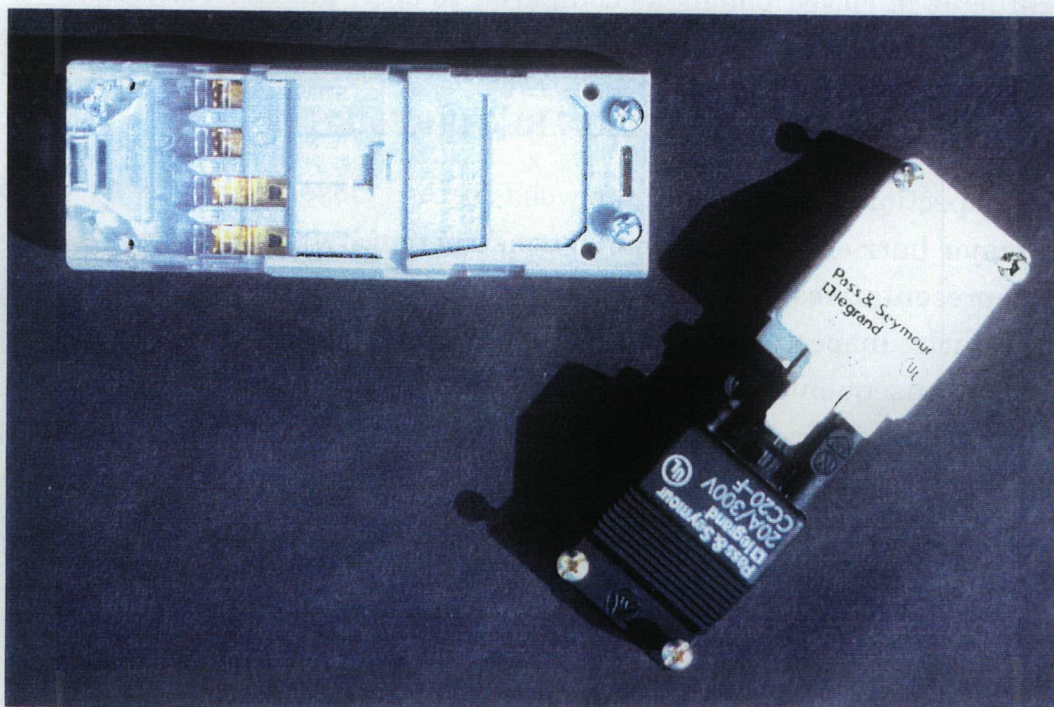


Figure 6.3
Nonmetallic Wiring Splices

Perhaps the greatest argument against closed panels is the difficulty of performing modifications in the field. Manufacturers may leave panels open in areas where large numbers of electrical connections are to be made as in areas around circuit breakers.

Plumbing

Plumbing is frequently not accommodated in panel systems. As with wiring, a varying degree of plumbing installation can be accommodated in a closed panel. Vent stacks can be easily installed in the panel. Greater degrees of piping become more difficult to accommodate. Manufacturers may choose to leave panels open in areas where plumbing is to occur such as in bathrooms and kitchens.

Joints

Because closed panels are finished in the factory, discontinuities exist between panel joints unlike with open panels where drywall can be staggered and vapor barriers span panel joints. Consequently, developing diaphragm action in walls

is more difficult in closed panels as compared to open panels. Therefore, connection of panels must be adequate to develop shear strength.

6.2 CODES AND INSPECTION REQUIREMENTS

Code and inspection requirements for wood-framed closed panels were often listed as major barriers to closed panel construction by manufacturers and industry representatives. Manufacturers often listed the inspection process as the greatest obstacle. Inspection in the field is not possible with closed panel construction; consequently, codes require a quality assurance program and inspections in the factory. In addition, there is a lack of uniformity between codes at the state and national level, which requires manufacturers to go through several different code approval processes. However, many of these problems have been overcome by the SSIC panel industry, which produces panels that are closed.

Codes and inspections represent a legitimate barrier to wood-framed closed panel construction. Codes are written in legal form, which can often be confusing. In addition, the same code is often open to different interpretations among different code officials and different jurisdictions. The code and inspection process also represents an added expense for manufacturers.

Codes and inspections is also an area where perceived barriers are great, as often a wood-frame open panel manufacturer is unaware of the code approval process for a wood-frame closed panel. For example as stated earlier, one Oregon open panel manufacturer believed that in order to build closed panels every closed panel home would be required to be inspected in the factory as well as in the field. The Oregon manufacturer was unaware of the Oregon State Building Codes manufactures' compliance program, which allowed manufacturers to establish a quality assurance program requiring only biannual inspections of the facilities.

6.3

CONSTRUCTION TRADES

Wood-frame closed panels reduce the need for subcontractors at the site; however, they do not entirely eliminate trades. For example, closed panels may already be finished with gypsum wallboard; however, the ceilings will also need to be finished. Panel manufacturers often believe trades such as gypsum wallboard hangers, electricians and plumbers resist the introduction of closed panels in their areas. Manufacturers fear that wallboard contractors may charge a premium for work on closed panel construction, because it reduces the wallboard contractors earning potential. Construction trades, in general, may charge more for working with closed panels due to their lack of experience with a new panelized product.

A case of the resistance a trade may exhibit to wood-framed closed panel construction occurred locally in Oregon. A wood-framed closed panel manufacturer was seeking to increase the finished quality of their panels by adding wiring in the factory. Essential to the wiring was the use of a nonmetallic wiring splice being produced for HUD code double wides. Initially, the Oregon manufacturer was given permission to use the wiring device and to wire the panels in the factory. However, midway through the construction process for the initial wood-framed closed panel home the inspector was changed. The new inspector would not allow the use of the non-metallic splice in the field as well as the wiring of panels in the factory. Currently, the issue is before the State of Oregon Chief Electrical Inspector. In addition, the Building Codes Division only allows the installation of conduit and electrical boxes in a panel by a licensed electrician, and the installation of any wire in the factory must be inspected by a Building Codes official.

Chuck Monschein of the Oregon State Building Codes Agency would like to modify the Oregon compliance program to allow electrical wiring. Monschein does not foresee any changes in the regulations concerning the wiring of panels in the factory.

In general, wood-framed closed panels are a new construction technique that disrupts the traditional sequence of light frame wood construction and alters and

work performed by trades. The construction trade has generally been slow to adopt new forms of construction, especially forms of construction that minimize labor for certain trades.

6.4 SHIPPING AND TRANSPORTATION

Because closed panels are finished on both sides, they require greater care in shipping to minimize damage. The finished layer of drywall is the most susceptible to damage. Panels must also be protected from exposure to rain as well as protected from impact damage. The additional precautions necessary for closed panels add costs that are not inherent to open panels.



Figure 6.4
Unloading Wood-Framed Closed Panel from Flatbed Truck

Planning and sequencing of panel construction begins in the factory before construction begins. Shipping of the panel must be considered in the sequence of construction. Panel segments are often constructed in reverse sequence so that the last panel constructed and loaded for shipping is the first panel installed in

the field. Panels must be secured when in transportation to prevent damage, but must also be easy to remove from the transport vehicle.

Inherent to the planning of a panelized home is clear communication. All panels must be clearly labeled and referenced to plans for ease of installation. Lines of communication between designers, the manufacturing personnel and the construction personnel must be well established.

6.5 LACK OF AWARENESS OF BUILDERS AND OWNERS

In general, residential builders and owners are unaware of the benefits of wood-framed closed panels. Often, the general public perceives a loss of craftsmanship and quality in industrialized housing. Prospective home owners are unaware of the potential energy and cost savings inherent in industrialized housing components.

6.6 LACK OF KNOWLEDGE CONCERNING MANUFACTURING FACILITIES

Manufacturers currently producing wood-framed open panels and not wood-framed closed panels often listed the cost of new manufacturing equipment as a barrier to producing closed panels. One manufacturer believed the cost of equipment needed to change his open panel line to a closed panel line was in the range of \$100,000 to \$150,000. The primary piece of equipment required was a device to flip the panels to allow work on both sides of the panel to occur. The cost of a wall flipper, according to one manufacturer, was \$8,000 to \$9,000 dollars. Closed panels can incur greater up front costs for purchase of materials. Another concern was how to include additional manufacturing space for storage of materials for production of closed panels.

6.7 PERCEIVED LOSS OF DESIGN FLEXIBILITY

Manufacturers of open panels often cite the loss of flexibility in the design of housing they produce as a barrier to wood-framed closed panel production. The fear of loss of flexibility in design translates into a fear of market loss.

7.0

STRATEGIES TO REMOVE MARKET BARRIERS

The survey of manufacturers and industry representatives highlights that a multifaceted approach is required to reduce barriers to closed panels. Strategies to reduce barriers include further research, technical innovation, and education of builders, manufacturers and the public. Specific strategies to overcome each barrier are listed below:

Barrier: Lack of Flexibility

- Innovations in household wiring
 - nonmetallic splices
 - integrated raceways
 - infrared light switching
- Innovations in foundation connections
- Greater use of on-site construction cranes for residential scale projects. On-site construction cranes are common for construction of projects of all scales in Europe.
- Increased computerization in field and factory to facilitate production and communication

Barrier: Codes and Inspections

- Regional uniformity in codes for factory built panels
- Reciprocity between the ICBO Agency and state and local jurisdictions
- Increased adoption of Manufacturing Compliance Programs
- Reciprocity between states and local jurisdictions
- Development of a manufacturing consortium to share costs for code approval and testing of panel designs

Barrier: Construction Trades

- Education of trades to new methods of construction
- Incorporation of trades into manufacturing process

Barrier: Shipping and Transportation

- Increased durability of finish skin through the wise use of more

• durable materials such as fiber reinforced gypsum board rather than conventional gypsum board

- Advances in storage containers made specifically for the shipment of panels to facilitate the loading and unloading of panels as well as their protection in transport

Barrier: Lack of Awareness of Builders and Owners

- Research on the cost effectiveness of closed panels
- Research on increased energy efficiency and cost effectiveness of closed panels
- Construction of demonstration houses for testing and promotion
- Development of educational material to disseminate knowledge of the benefits of wood-framed closed panels

Barrier: Lack of Knowledge Concerning Manufacturing Facilities

- Cost studies on conversion from open panel manufacturing to closed panel manufacturing
- Development of educational material for manufacturers

Barrier: Perceived Loss of Design Flexibility

- Design of panels as a kit of parts that allows multiple uses in house design
- Greater use of computerization in design and the factory to allow quick revisions to standard designs

8.0

REFERENCES

- Brown, G.Z., P. Kumar, and P. Larocque. *University Housing Thermal Testing Report*, Center for Housing Innovation. University of Oregon. September, 1995.
- Rosenbaum, George. "Production Builders Report 13% Climb." *Automated Builder*, Carpinteria, CA. January, 1995.
- Sellens, Charles. "Japan Wants to Import Panelized Homes." *Automated Builder*, Carpinteria, CA. November, 1993.
- State of Oregon's Building Codes Division, *Manufacturer's Compliance Control Program Information Packet*, Salem, OR.

A.1

SURVEY

Building Panels Manufacturers' Survey

Please take a few minutes to fill out the following information. Then fold, tape, and drop in the mail. Thank you.

Name _____ Title _____
 Company _____
 Address _____
 City _____ State _____ ZIP Code _____
 Phone _____ FAX _____

Does your company produce building panels? ☐ Yes ☐ No If "No", stop here; please return for our records.

What percentage sales are to residential applications versus commercial applications? Residential % Commercial %

What type(s) of panels does your company produce? ☐ Basement ☐ Floor ☐ Roof
☐ Exterior Wall ☐ Ceiling
☐ Interior Wall ☐ Other _____
 Check all that apply.

We are interested in the condition of the panels as shipped (i.e., not including additions when installed). Please describe the panels as they leave the factory. If you make more than one type of panel, please copy this form for each type.

Do your panels carry gravity (non-lateral) loads? ☐ Yes ☐ No

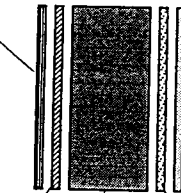
If yes, what part of the panel primarily carries the load? ☐ Stressed skin ☐ Steel studs
☐ Steel frame ☐ Wood studs
☐ Wood frame ☐ Other _____

What is the exterior skin?

- ☐ None
- ☐ Brick
- ☐ Log
- ☐ Vinyl
- ☐ Plywood (T1-11)
- ☐ Oriented Strand Board (LP)
- ☐ Hardboard (Masonite)
- ☐ Wood siding
- ☐ Metal
- ☐ Fiberglass
- ☐ Stucco
- ☐ Shingles
- ☐ Other _____

If any additional exterior layer, what is it?

- ☐ None
- ☐ Plywood
- ☐ Oriented Strand Board
- ☐ Hardboard
- ☐ Air barrier (Tyvek)
- ☐ Metal
- ☐ Rigid insulation
- ☐ Insulating sheathing
- ☐ Fiberglass
- ☐ Other _____



What is the interior skin?

- ☐ None
- ☐ Plywood
- ☐ Oriented Strand Board
- ☐ Hardboard
- ☐ Metal
- ☐ Fiberglass
- ☐ Brick
- ☐ Log
- ☐ Drywall/Gypsum Board
- ☐ Other _____

Insulation type?

- ☐ Urethane foam
- ☐ Polyisocyanurate
- ☐ Cellulose
- ☐ Fiberglass batt
- ☐ Expanded polystyrene (bead board)
- ☐ Extruded polystyrene (styrofoam)
- ☐ Other _____

If any additional interior layer, what is it?

- ☐ None
- ☐ Vapor Barrier
- ☐ Plywood
- ☐ Oriented Strand Board
- ☐ Hardboard
- ☐ Rigid insulation
- ☐ Metal
- ☐ Fiberglass
- ☐ Other _____

Please check all that apply

Do panels have

- ☐ Windows ☐ Doors ☐ Neither

How is electrical wiring accommodated?

- ☐ Not accommodated ☐ Wiring cavity routed
- ☐ Optional/Custom ☐ Plastic/metal conduit
- ☐ NM (Romex) ☐ Pre-installed boxes
- ☐ Armored Cable/BX ☐ Other _____

How is plumbing accommodated?

- ☐ Not accommodated
- ☐ Optional/Custom
- ☐ Plumbing cavity routed
- ☐ Preinstalled plastic/metal pipe
- ☐ Other _____

How are the panels connected to each other?

- ☐ Tongue and groove joint
- ☐ Cam lock (or other connector)
- ☐ OSB/plywood strip spline
- ☐ Lumber spline
- ☐ Other _____

What sizes of panels are available?

- ☐ 4'x8'
- ☐ 8'x24'
- ☐ Other standard _____
- ☐ Custom to _____ width, _____ length

What overall thickness is a panel?

- ☐ 4" ☐ 8" ☐ 12"
- ☐ 6" ☐ 10" ☐ Other _____

What is your principal market area?

- ☐ Less than 300 mile radius
- ☐ Northeast U.S.
- ☐ Northwest U.S.
- ☐ Midwest U.S.
- ☐ Southeast U.S.
- ☐ Southwest U.S.
- ☐ International
- ☐ Other _____

How are your panels shipped?

- ☐ Container
- ☐ Horizontal/flat
- ☐ Vertical/on end
- ☐ Other _____

To whom do you supply panels?

- ☐ Building contractor
- ☐ Owner/builder
- ☐ Own construction firm
- ☐ Other _____

Thank you for completing the survey. Please refold, tape, and mail. If you have any questions, contact Therese Peffer at 503-346-5647, FAX: 503-346-3626, E-mail: tpeffer@aaa.uoregon.edu

Therese Peffer
 Energy Studies in Buildings Laboratory
 University of Oregon
 Department of Architecture
 Eugene, OR 97403

A.2

SURVEY RESULTS

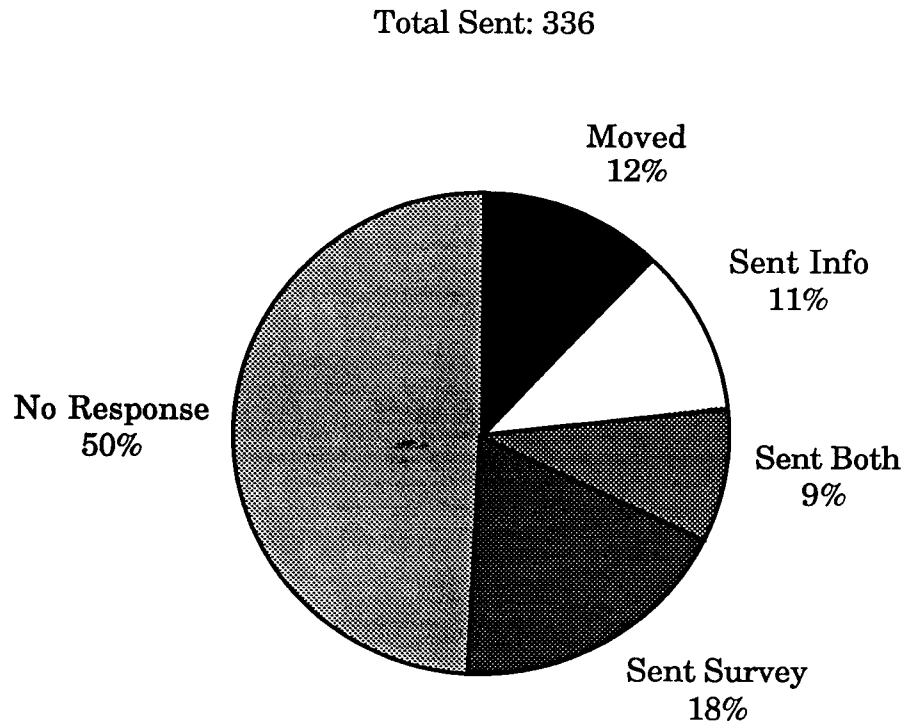


Figure A.2.1
Response to Survey

What percentage of sales are to residential applications versus commercial applications?

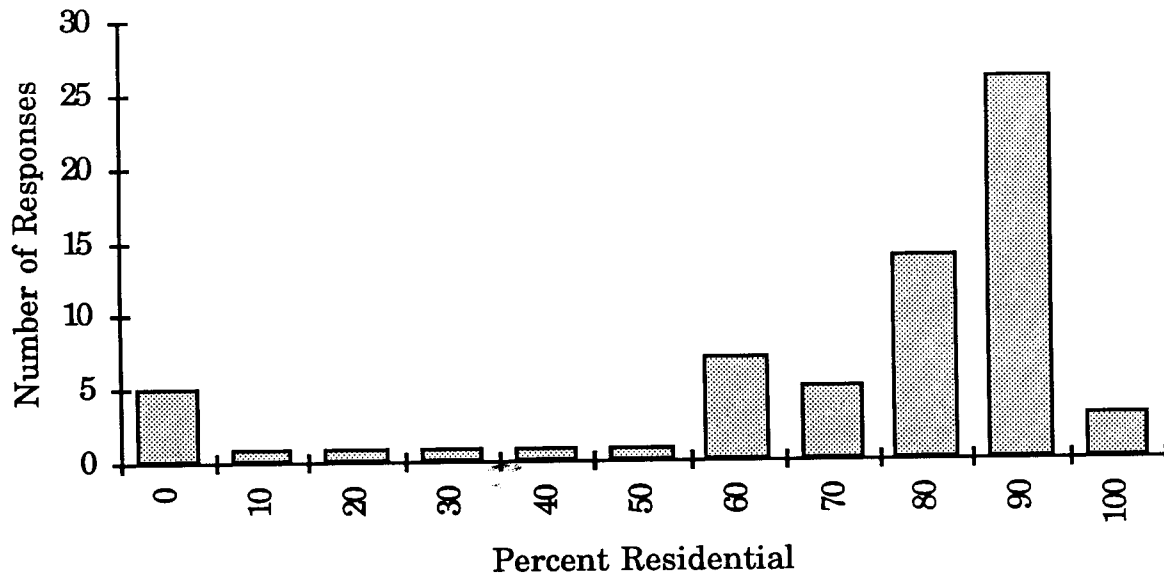


Figure A.2.2
Distribution of Manufacturers' Production of Panels for Residential Markets

Average of responses: Residential 72.5%, Commercial 27.5% (Median response:
Residential 80%, Commercial 20%)

What type(s) of panels does your company produce?

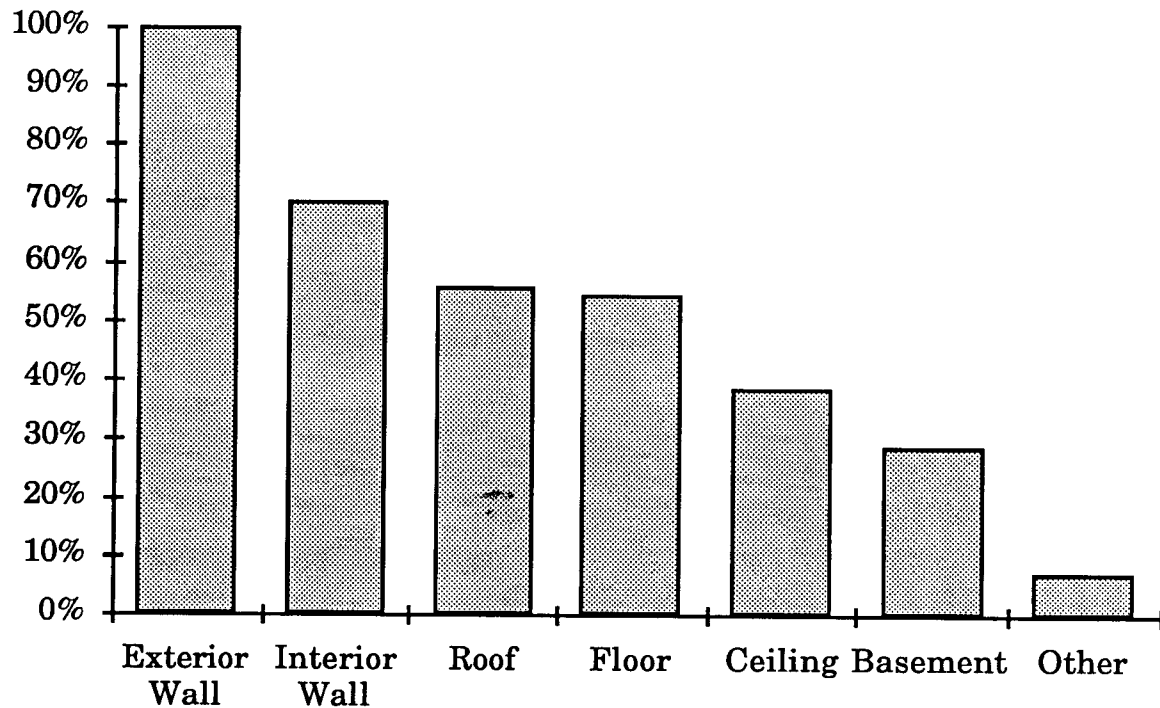


Figure A.2.3
Types of Panels Produced by Manufacturers

Number of Responses: 71 Exterior Wall, 49 Interior Wall, 39 Roof, 38 Floor, 27 Ceiling, 20 Basement. Write in responses included foundation (2), freezer/cooler (2), and curtain wall.

Do your panels carry gravity (non-lateral) loads?

Number of Responses: 63 Yes, 7 No

If yes, what part of the panel primarily carries the load?

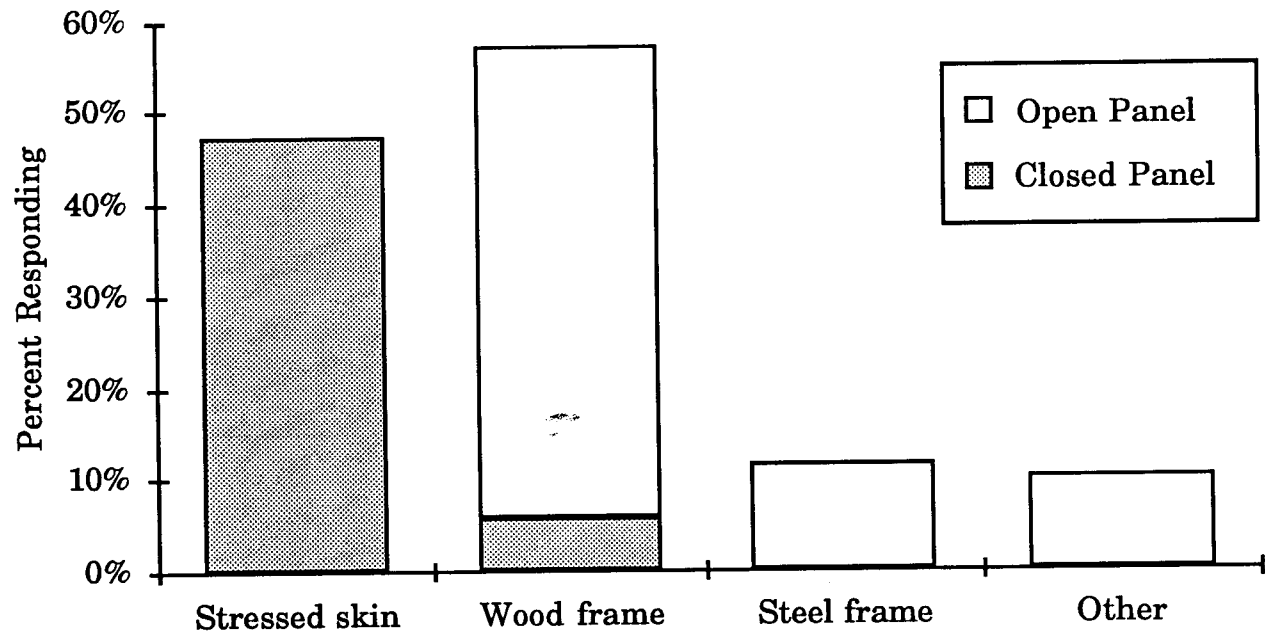


Figure A.2.4
Distribution of Panel Structure

Number of Responses: Stressed skin 33, Wood studs 26, Wood frame 14, Steel studs 7, Steel frame 3 (Other responses: urethane and PVC studs molded in place, LVLs, steel tubes (2), concrete studs, straw core, Portland cement plaster and wire mesh pattern).

What is the exterior skin?

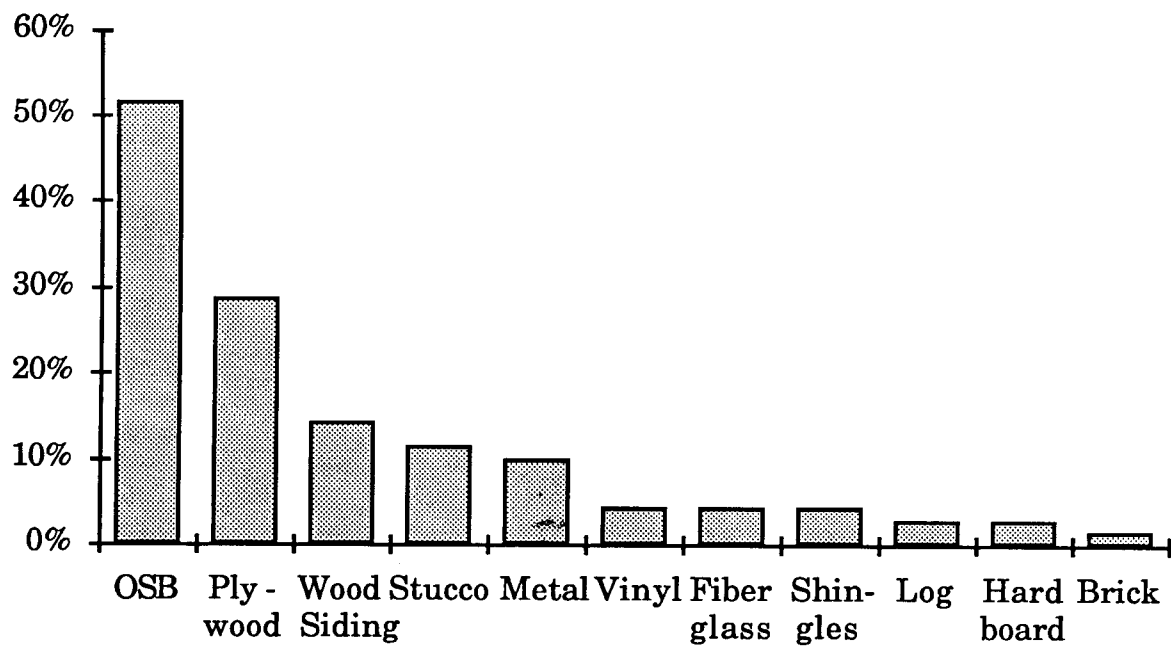


Figure A.2.5
Distribution of Types of Panel Skin

Number of Responses: OSB 36, brick 1, log 2, vinyl 3, plywood 20, hardboard 2, wood siding, metal 7, fiberglass 3, stucco 8, shingles 3.

If any additional exterior layer, what is it?

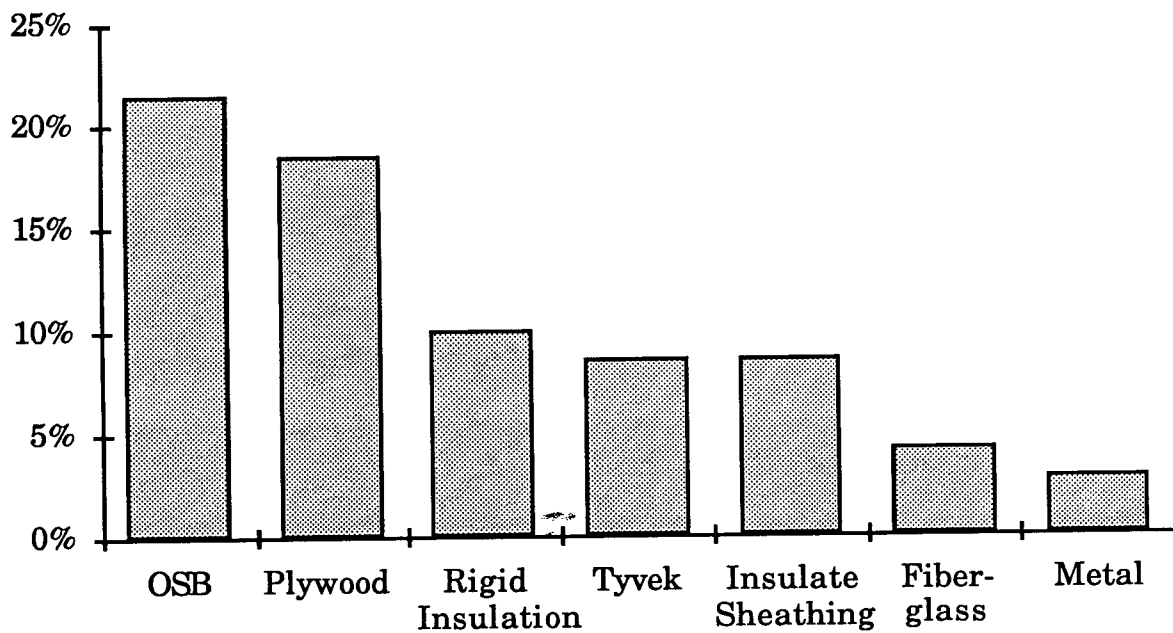


Figure A.2.6
Types of Exterior Panel Layers

Number of responses: Plywood 13, OSB 15, hardboard 0, tyvek 6, metal 2, rigid insulation 7, insulation sheathing 6, fiberglass 3.

What is the interior skin?

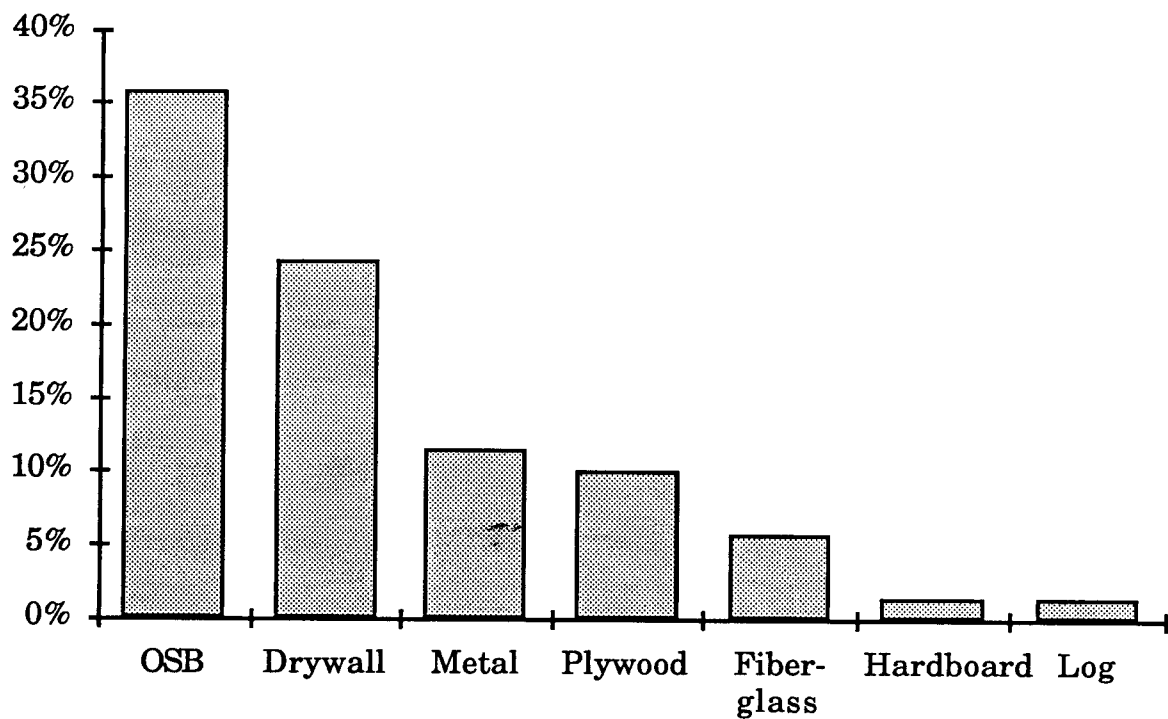


Figure A.2.7
Types of Interior Panel Layers

Number of responses: Plywood 7, OSB 25, hardboard 1, metal 8, fiberglass 4, brick 0, log 1, drywall/gypsum board 17.

If any additional interior layer, what is it?

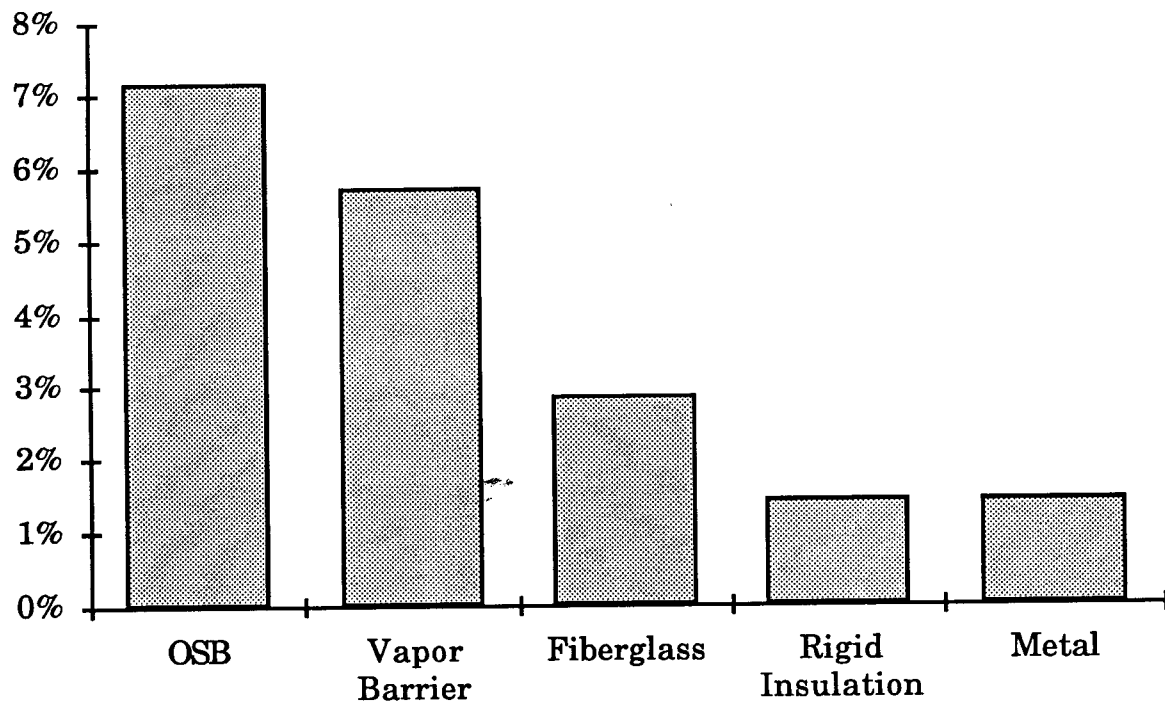


Figure A.2.8
Types of Additional Interior Panel Layers

Number of Responses: Vapor barrier 4, plywood 0, OSB 5, hardboard 0, rigid insulation 1, metal 1, fiberglass 2.

Do panels have windows, doors or neither?

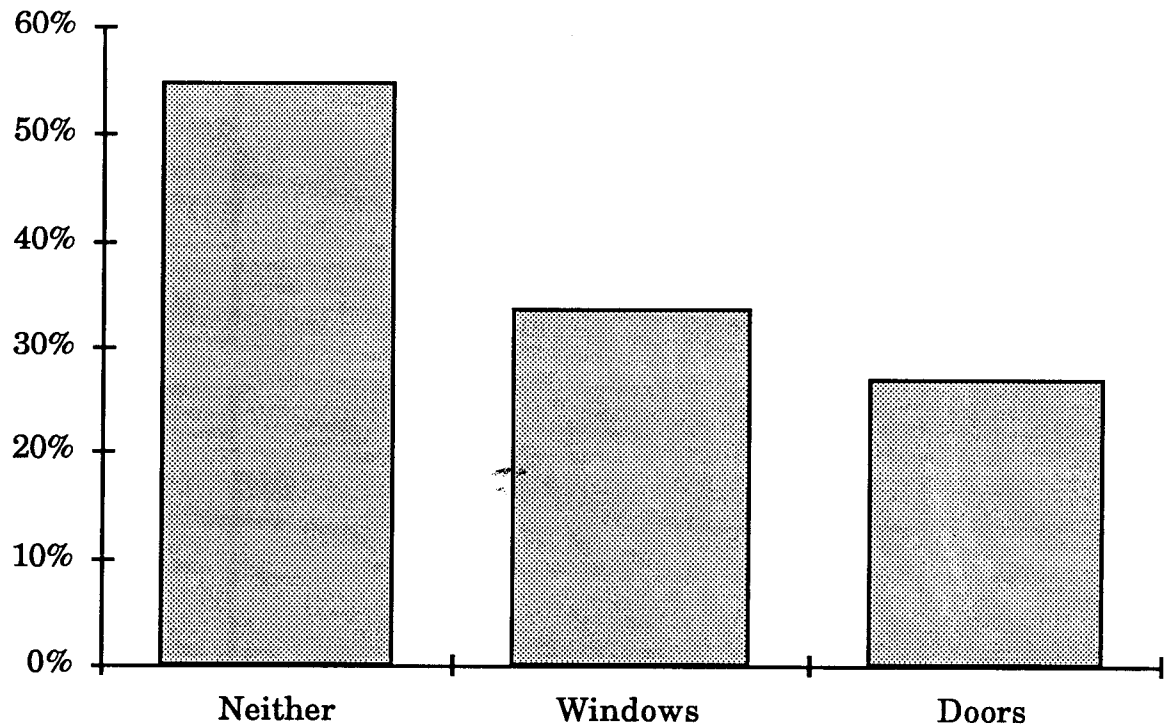


Figure A.2.9
Distribution of Panel Manufacturers Who Add Windows and Doors to Panels

Number of responses: windows 24, doors 19, neither 39.

How is electrical wiring accommodated?

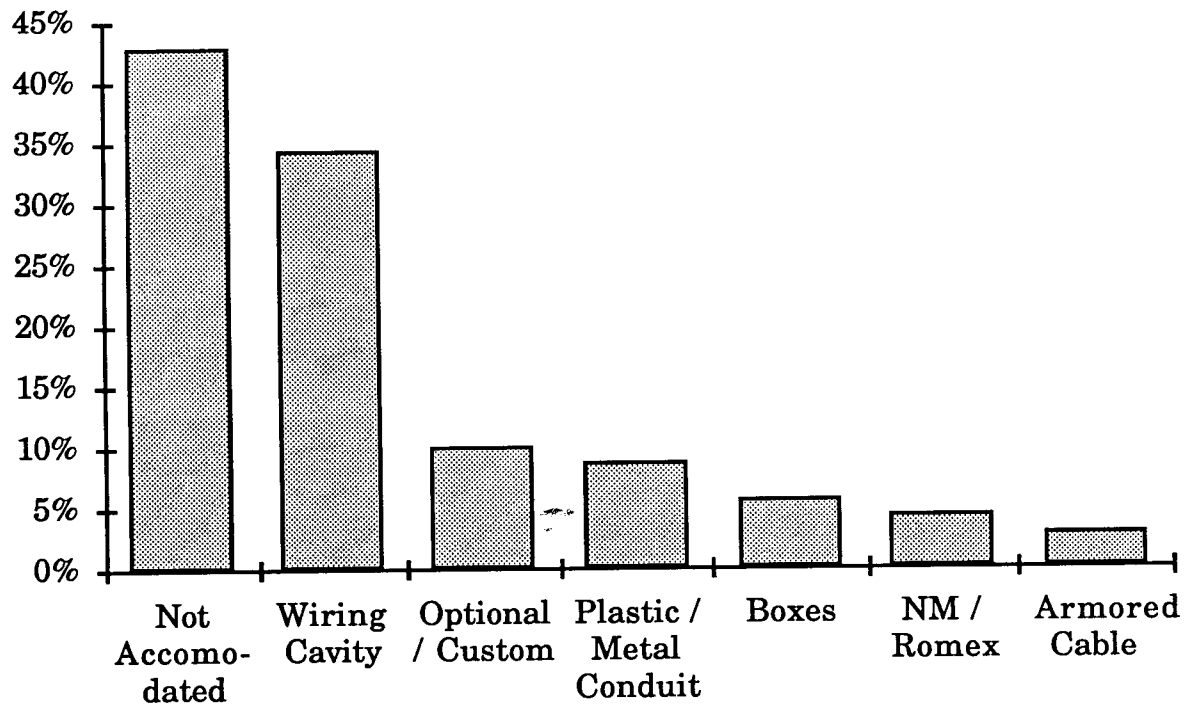


Figure A.2.10
Methods of Accommodating Wiring in Panels

Number of responses: Not accommodated 30, optional/custom 7, NM (Romex) 3, armored cable/BX 2, wiring cavity routed 24, plastic/metal conduit 6, preinstalled boxes 4.

How is plumbing accommodated?

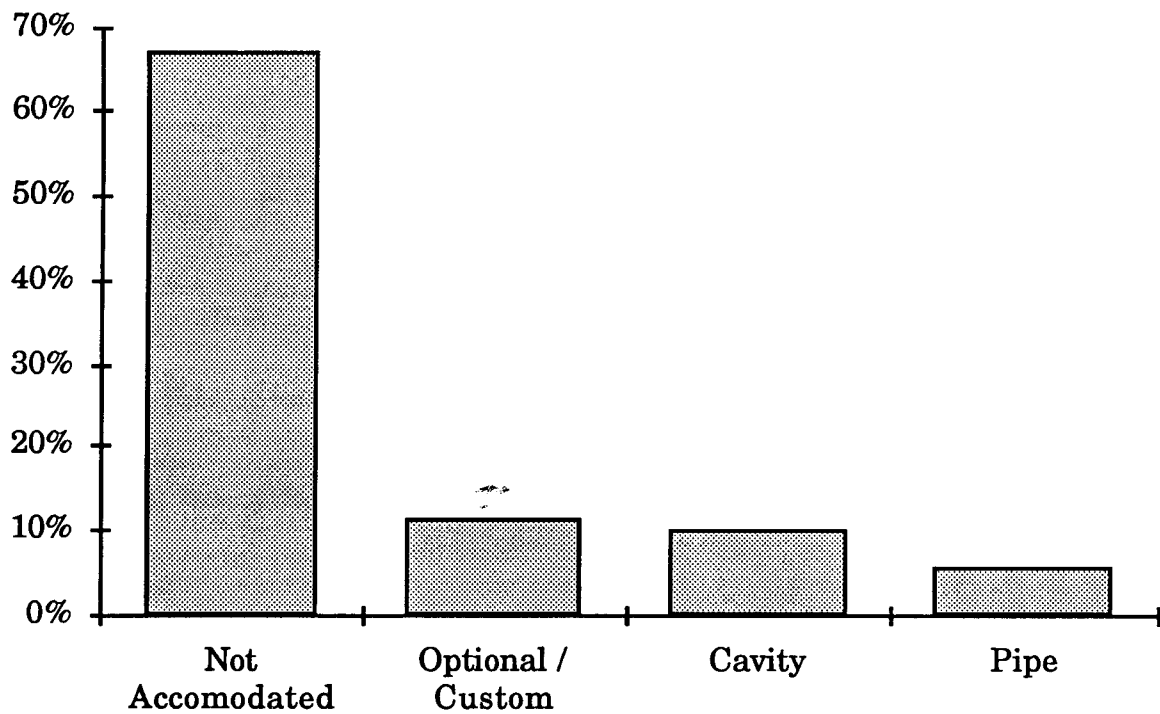


Figure A.2.11
Methods of Accommodating Plumbing in Panels

Number of Responses: Not accommodated 47, optional/custom 8, plumbing cavity routed 7, preinstalled plastic/metal pipe 4.

How are the panels connected to each other?

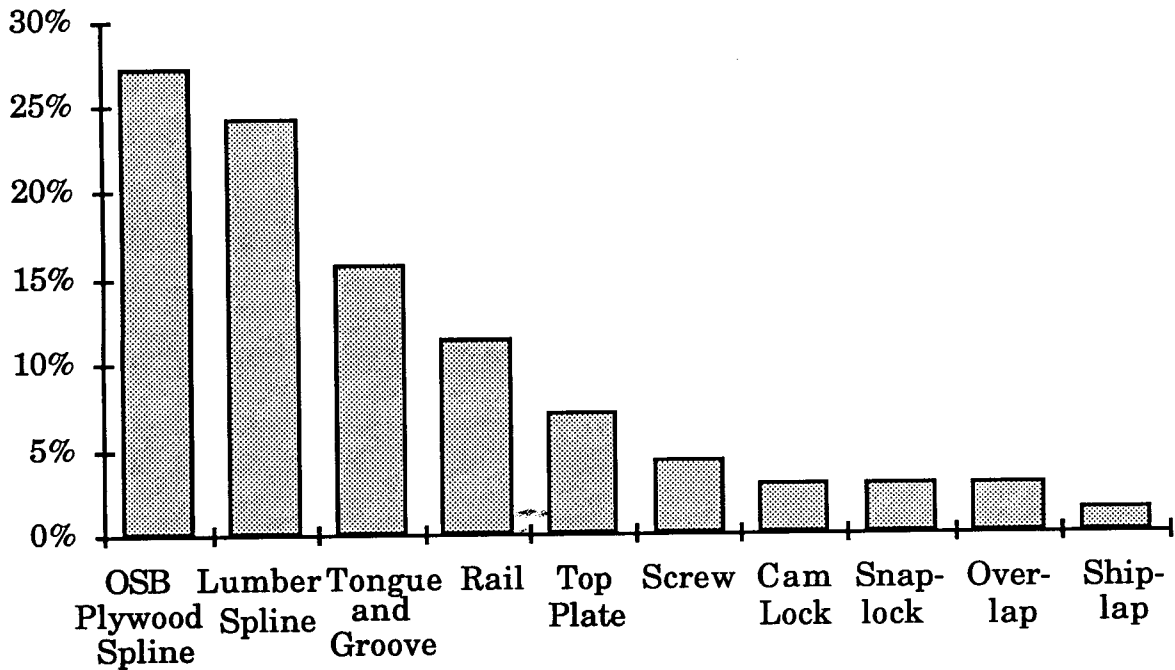


Figure A.2.12
Methods of Connecting Panels Used by Panel Manufacturers

Number of Responses: Tongue and groove joint 11, Cam lock (or other connector) 2, OSB/plywood spline 19, lumber spline 17. Other: snaplock 2, shiplap 1, overlap 2, top plate 5, screw 3 and rail 8.

What sizes of Panels are available?

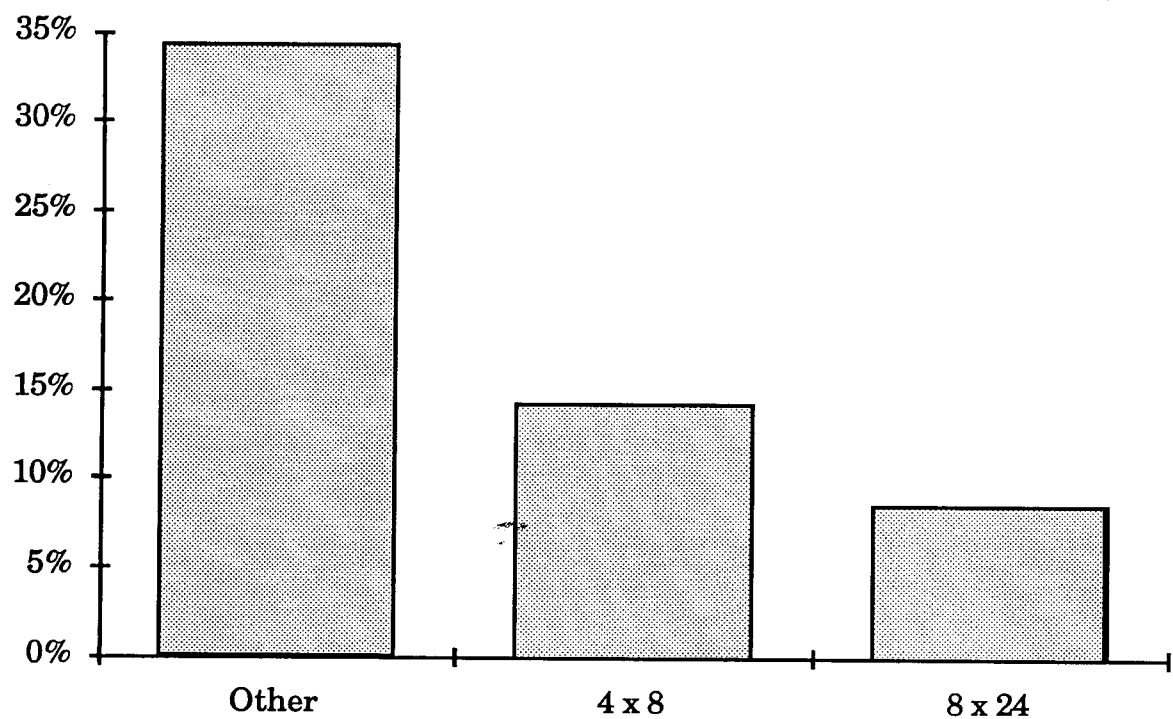


Figure A.13
Distribution of Panels by Size

Number of Responses: 4'x8: 10, 8'x 24: 6, Custom: 24

What overall thickness is a panel?

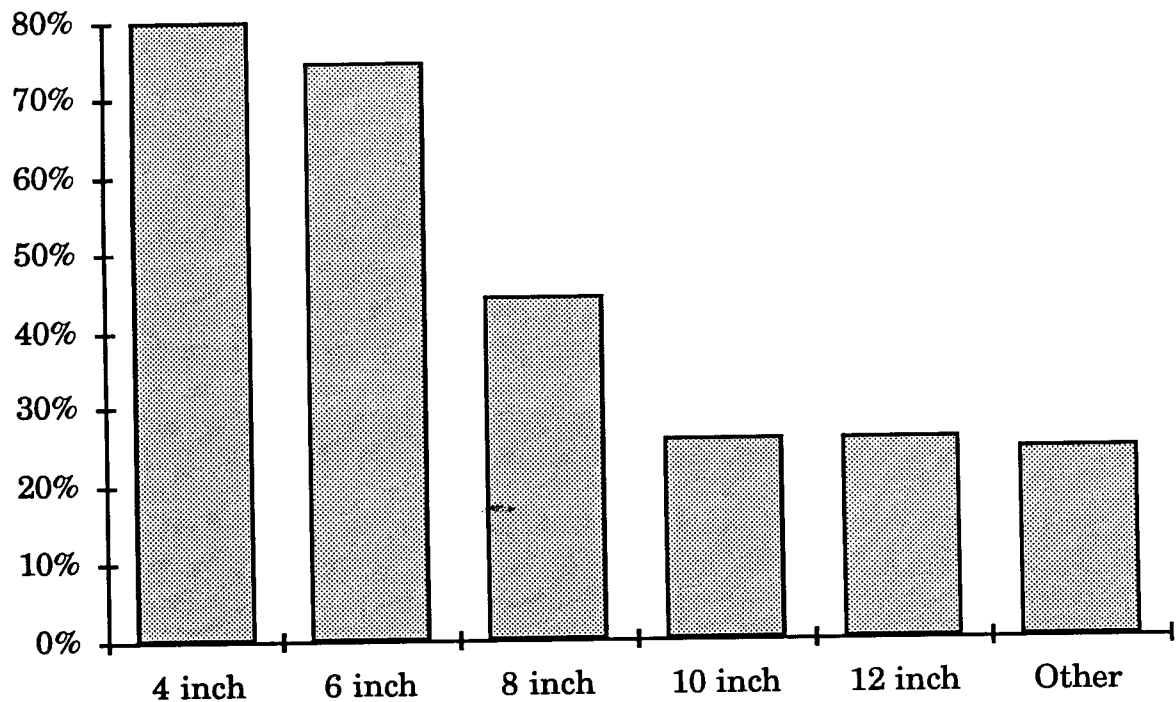


Figure A.2.14
Distribution of Panels by Thickness

Responses: 4 inch: 56, 6 inch: 52, 8 inch: 31, 10 inch: 18, 12 inch 18, other: 17.
Other includes: 2 inch, 3 inch, 5 inch, 14 inch, match lumber sizes,
as specified, custom, 1/8 inch, as design requires, and 1/2" to 2".

What is your principal market area?

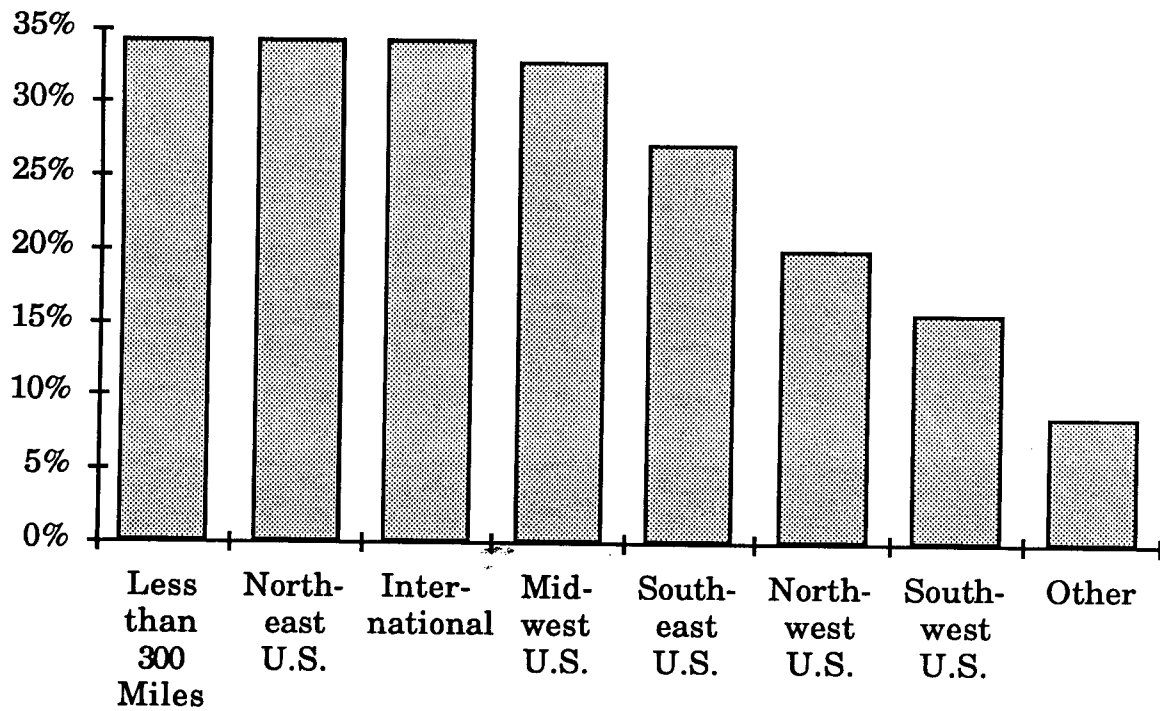


Figure A.2.15
Distribution of Markets for Panel Manufacturers

Number of Responses: Less than 300 mile radius 24, Northeast U.S. 24,
Northwest U.S. 14, Midwest U.S. 23, Southeast U.S. 19,
Southwest U.S. 11, International 24. Others: Rocky
Mountain, South, Entire, Mid Atlantic, Alaska/Hawaii.

How are your panels shipped?

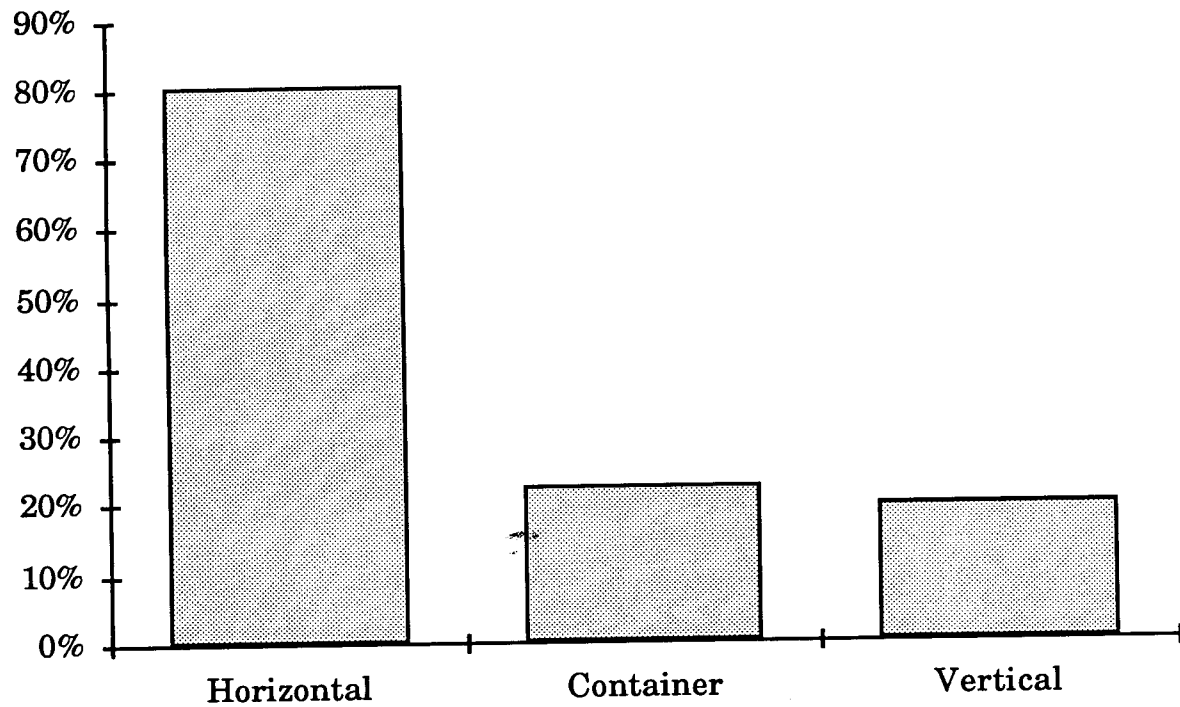


Figure A.2.16
Methods of Shipping Panels

Number of Responses: Container 16, Horizontal / Flat 57, Vertical 14

To whom do you supply panels?

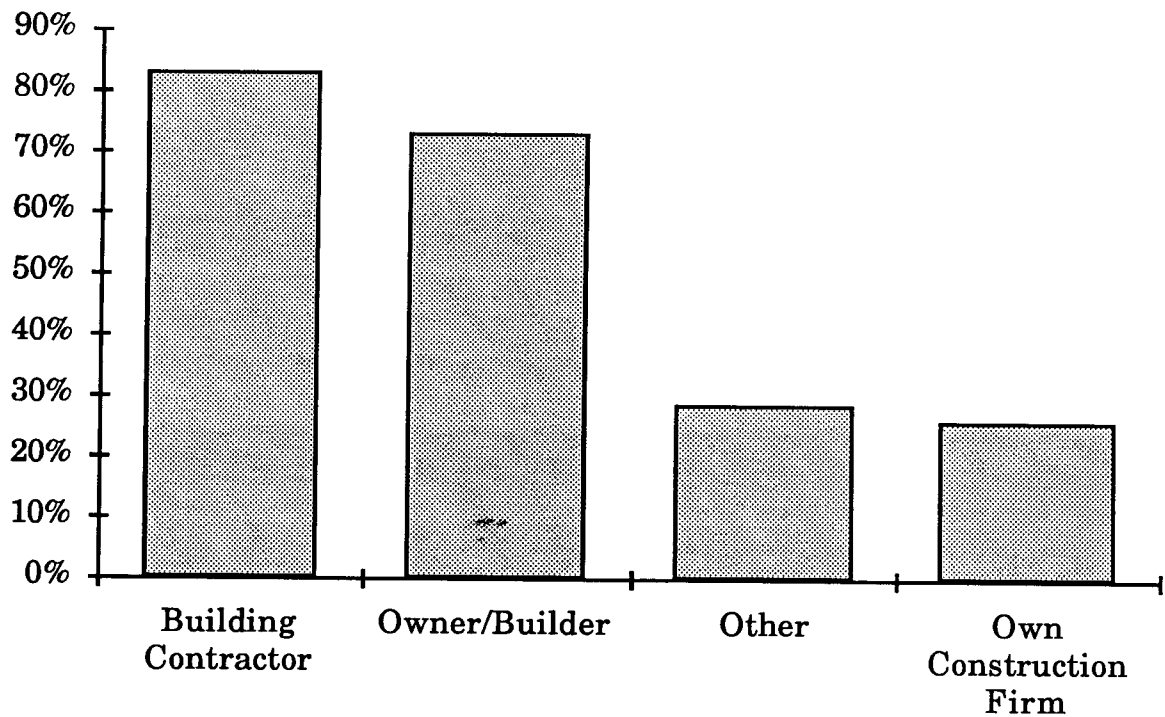


Figure A.2.17
Distribution of Panels to Buyers

Number of Responses: Building Contractor 58, Owner Builder 51, Own Construction Firm 18, Other 20. Other includes subcontractor 1, broker 1, trading company 1, individuals 3, lumberyard 1, all 2, developer 2, distributor 6, sales organization

A.3 OBSERVATION OF MANUFACTURING AND CONSTRUCTION

The manufacturing facility of Soft Tech, a producer of wood-framed closed panels in Springfield, Oregon, was visited to observe the manufacturing process of wood-framed closed panels. The manufacturing process was video taped for future study.

Manufacturing Facilities:

Soft Tech's Manufacturing facilities consist of approximately 20,000 square feet of manufacturing area. The facilities were organized into two lines, a north and a south line, approximately 100 feet long. Both lines consisted of roller decks with materials spaced along the line as needed. Compressed air lines ran transversely to the line to power equipment.

Major equipment on the northern line included a track nailing gun manufactured by Carlson Systems of Omaha, Nebraska. Approximately two thirds of the way down the line was a custom made "flipper" to rotate panels so that both sides could be worked on in one line. The flipper, manufactured locally by LDH Welding, was primarily a cantilevered crane with an axle approximately six to eight feet above the line. Large canvas straps were harnessed to the axle. The straps would be wrapped under the panel and the axle would then be rotated to flip the panel. The factory manager explained that the flipper allowed the line to continue without creating a split offset line as other manufacturers use.

The southern line was organized similarly to the northern line except that a track nailing gun was not present. Soft Tech had fabricated a custom-made nailing jig which utilized a traditional hand-held pneumatic nailing gun.

Soft Tech can output 20 panels a day with approximately 14 people. The construction of the closed panel occurs on the north line with five stations. Often workers were dedicated to a specific station. Several workers were floating between two stations as work was needed. The five stations are as follows.

Wood-Framed Closed Panel Stations

Framing

Wallboard and Polyethylene Membrane

Flipping Station

Siding Station

Loading Station

Description of the Manufacturing Process

On the day of the factory visit, Soft Tech was manufacturing wood-framed closed panels for a two-story duplex for Springfield, Oregon. The factory portion of this job was anticipated to last approximately one week. The job began with prep work for actual line construction. All the framing lumber was precut in approximately one day. All the framing and assemblies were then constructed in approximately half a day. Framing and assemblies include headers for doors and windows, garage openings, etc. In addition, a certified electrician preassembled components of conduit and electrical outlets.

Prep Work

- Precut framing (two people, one day)
- Assemble components
- Construct door and window headers
- Preassemble electrical conduit and electrical outlets
- Organize materials along the line for each station
 - adhesive
 - wall board
 - polyethylene membrane
 - insulation
 - oriented strand board
 - housewrap
 - windows and doors

- siding
- polyethylene membrane

Framing station (two people, one floater)

- Add bottom plate and top plate
- Add door and window assemblies
- Add studs and studs with electrical assemblies
- Secure frame in framing table
- Check dimensions and true
- Place adhesive on studs
- Place wallboard

Station 2 (one floater)

- Assist in placement of wallboard
- Rout out openings (generates waste)
- Apply polyethylene membrane
- Tack polyethylene membrane down with plywood strips

Station 3, Flipper Station (one to two dedicated workers, several floaters)

- Flip panel
- Insulate
- Add sheathing
- Add tie down straps for first-floor framing
- Add ropes for hauling

Stations 4 and Station 5, Siding Stations

- Add housewrap
- Add windows and doors
- Lay plumb line
- Install siding
- Install polyethylene membrane

Load Panel on Truck (10 minutes)

- Connect chains
- Lift panel and lower panel to check chains

- Adjust chains
- Place on truck
- Frame panel into truck and secure to existing panels

Common Problems of Construction

Backup on Line

One of the general problems on the line was backup of panels due to slower tasks such as installing siding. According to a Soft Tech employee, siding typically takes approximately 40 minutes a panel, whereas it typically takes approximately 25 minutes to frame a panel. A backlog of panels occurred on the line towards the end of the day, limiting space for framing.

Mislabeling

At the framing station there was some confusion related to a discrepancy with the drawings and the precut drywall, which appeared to be due to mislabeling.

Routing of Windows and Doors

In one instance, a door opening was not routed out at station 2. Consequently, the mistake was found at station 3. The polyethylene membrane to protect the panel had already been installed and had to be removed and reinstalled, causing a delay in the line.

Learning Curve.

Because Soft Tech generally does not manufacture completely finished closed panels, application of materials such as siding is not a skill possessed by all the workers. Consequently, there was a delay in installing the siding. The first panel took approximately 2.5 hours to side due to the learning curve.

Once the panels were manufactured they were transported to the field for installation. A crew of two removed the panels from the flat-bed truck, and a crew of four installed the panels. Erection of the first floor wall panels took approximately four hours. The second floor was then framed over the

next several days. The second floor wall panels were then erected in approximately five hours. A description of equipment, crew and problems encountered in the installation of panels follows:

Construction Equipment

Crane RT 522, 22.5 tons
Portable compressor
Traditional carpentry equipment
Flatbed trailer with metal framework

Construction Workers

Two lead carpenters
Two support carpenders
Two workers on flatbed
One crane operator

Panel Installation

- Connect panel to crane
- Detach panel from rigging on flat-bed truck
- Hoist panel
- Guide panel into place with guide ropes
- Remove plywood tack strips and polyethylene membrane inhibiting installation
- Lower panel to mud plate
- Detach crane
- True panel to existing panel using pry tool
- Nail panel to mud plate
- Remove hoisting ropes

Typical Installation Problems

- The panel fits snugly requiring use of crowbars and sledge hammers to install
- Holes accidentally knocked into the gypsum board
- Site communication sometimes difficult with noise of crane, requires yelling and use of hand signals

- According to Nick Skelton of Soft Tech, wet weather made unhitching panels difficult when working on ladders.
- According to Kurt Markus, co-owner of Soft Tech, the time required to detach panels from flatbed rigging was time-consuming with the in first house. Kurt thought they had been overcautious in securing panels.
- Workers are climbing around ladders and on panels, need to be mobile but may violate OSHA safety standards
- Difficulty with leveling long panels with short chains

If Soft Tech premanufactured floor cassettes, they could conceivably erect the entire duplex in one day. Currently the floor assembly is framed in the field. Although the first floor is wrapped in a secondary layer or polyethylene membrane, damage to the drywall is risked because the house is not weathered in.

Inspection of the interior of the first floor revealed no problems with water damage. Condensation behind the polyethylene membrane was common but did not appear to cause any damage.

Overall, the installation of the closed panels appeared to go quite smoothly with no major problems.